MISSION TO PLANET EARTH

TOPEX/POSEIDON

A United States/France Mission

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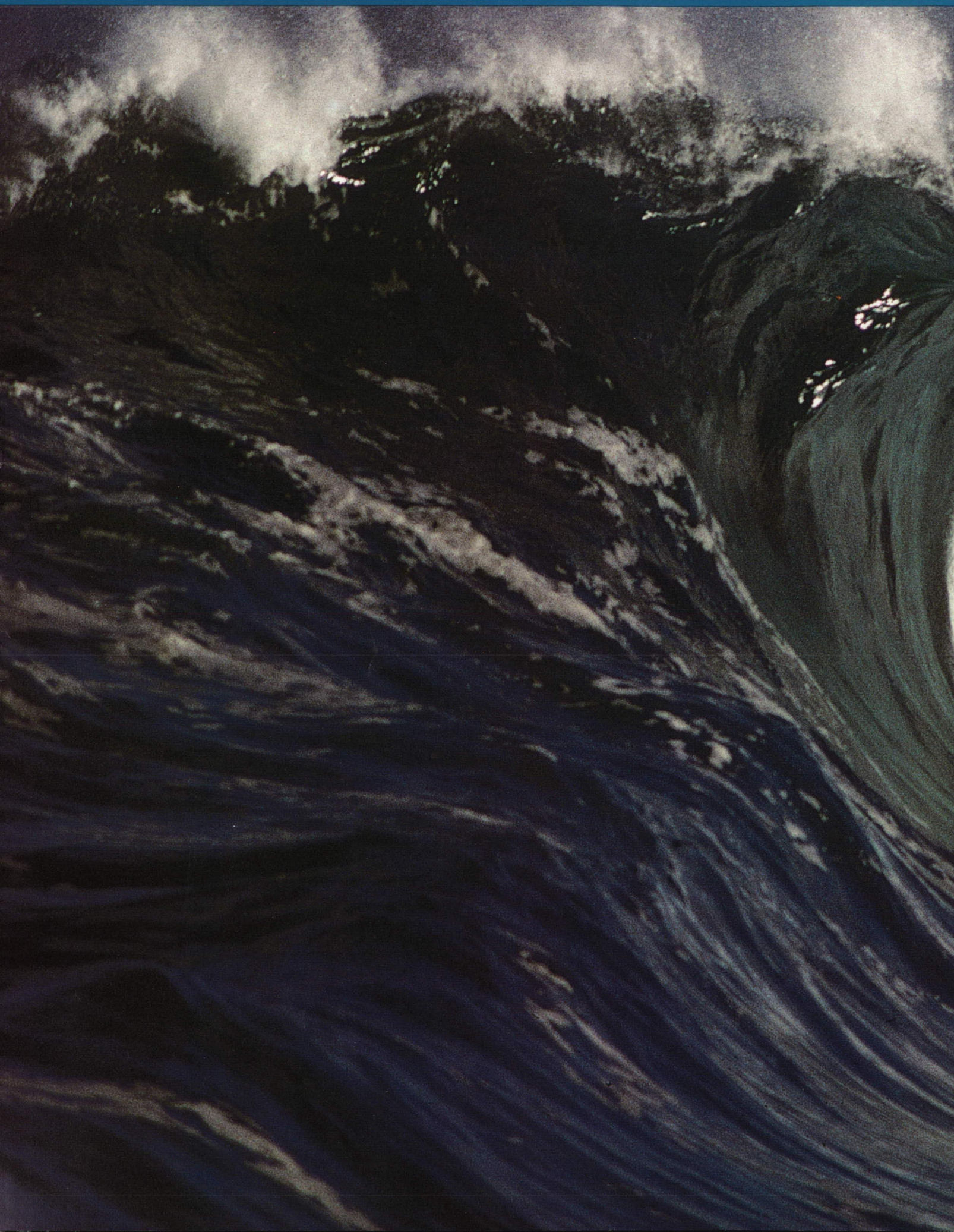
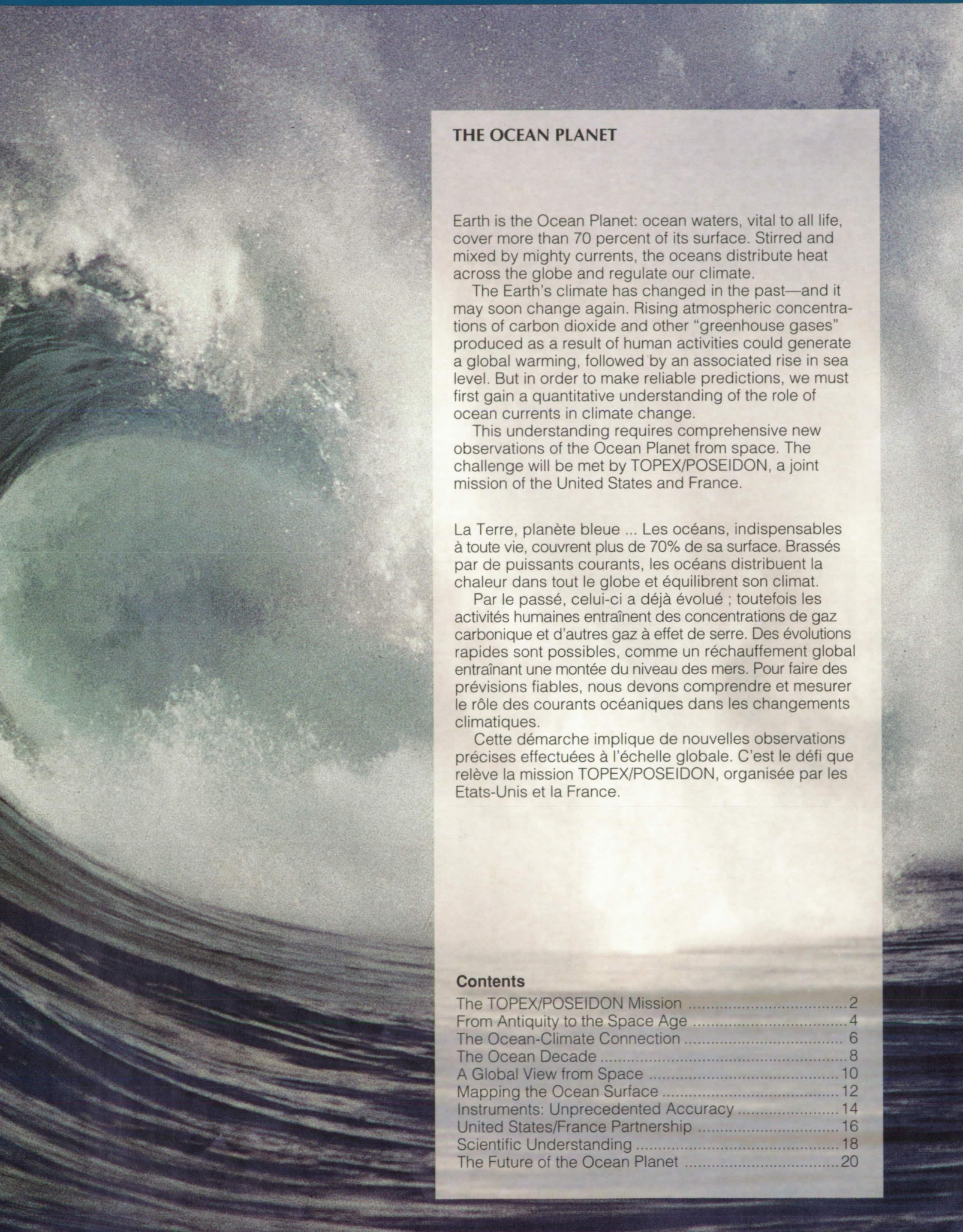
Oceanography From Space: The Oceans and Climate





THE OCEAN PLANET

Earth is the Ocean Planet: ocean waters, vital to all life, cover more than 70 percent of its surface. Stirred and mixed by mighty currents, the oceans distribute heat across the globe and regulate our climate.

The Earth's climate has changed in the past—and it may soon change again. Rising atmospheric concentrations of carbon dioxide and other "greenhouse gases" produced as a result of human activities could generate a global warming, followed by an associated rise in sea level. But in order to make reliable predictions, we must first gain a quantitative understanding of the role of ocean currents in climate change.

This understanding requires comprehensive new observations of the Ocean Planet from space. The challenge will be met by TOPEX/POSEIDON, a joint mission of the United States and France.

La Terre, planète bleue ... Les océans, indispensables à toute vie, couvrent plus de 70% de sa surface. Brassés par de puissants courants, les océans distribuent la chaleur dans tout le globe et équilibrent son climat.

Par le passé, celui-ci a déjà évolué ; toutefois les activités humaines entraînent des concentrations de gaz carbonique et d'autres gaz à effet de serre. Des évolutions rapides sont possibles, comme un réchauffement global entraînant une montée du niveau des mers. Pour faire des prévisions fiables, nous devons comprendre et mesurer le rôle des courants océaniques dans les changements climatiques.

Cette démarche implique de nouvelles observations précises effectuées à l'échelle globale. C'est le défi que relève la mission TOPEX/POSEIDON, organisée par les Etats-Unis et la France.

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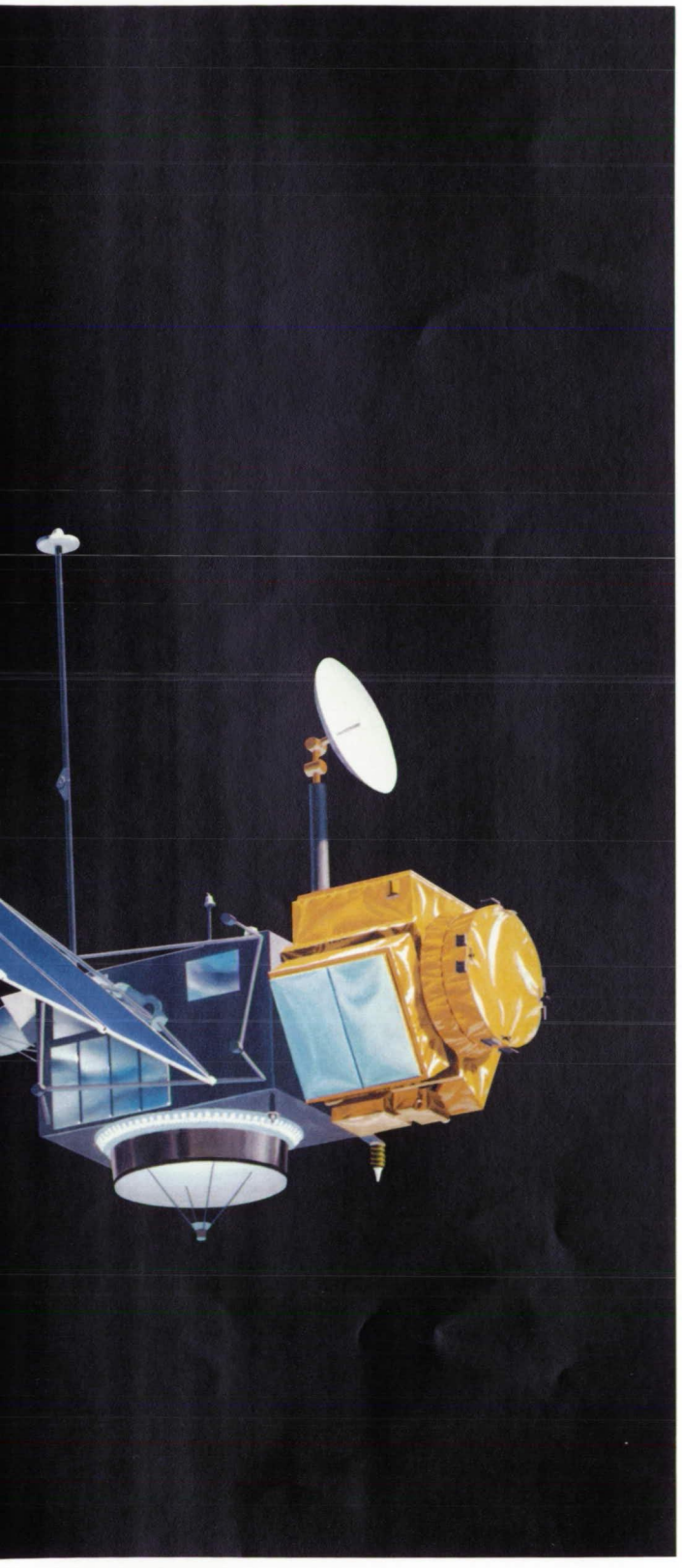
THE TOPEX/POSEIDON MISSION



The United States and France celebrate the International Space Year, 1992, with the launch of TOPEX/POSEIDON—the most advanced space mission ever designed to study ocean currents. The mission is sponsored by the U.S. National Aeronautics and Space Administration (NASA) and France's space agency, the Centre National d'Etudes Spatiales (CNES).

Sea-Surface Mapping from Space

TOPEX/POSEIDON will use radar altimetry to measure sea-surface height over 90 percent of the world's ice-free oceans. Circling the Earth every 112 minutes, the satellite will gather data for three to five years, carrying enough fuel for a full decade of operation. In combination with a precise determination of the spacecraft orbit, the altimetry data will yield global maps of ocean topography—the barely perceptible hills and valleys of the sea surface. From a knowledge of ocean topography, scientists can calculate the speed and direction of ocean currents worldwide.

United States/France Partnership

Joint planning was initiated in 1983. NASA, responsible for mission operations, is supplying the spacecraft and four instruments, including the primary radar altimeter. CNES is providing launch aboard an Ariane 42P expendable launch vehicle as well as two instruments, including an experimental altimeter. Management is provided by NASA's Jet Propulsion Laboratory and the CNES Centre Spatial de Toulouse.

Unprecedented Accuracy

From an altitude of 1,336 km (830 miles), TOPEX/POSEIDON will measure the distance from the satellite to the sea surface within 3 cm (1.2 inches). Three independent tracking systems will determine the position of the spacecraft within 10 cm (4 inches). These measurements will together yield accurate topographic maps over the dimensions of entire ocean basins—the primary mission objective. These data will permit quantitative studies of ocean circulation and its time variability that are crucial to an understanding of climate change.

Forecasts of Climate Change

TOPEX/POSEIDON is closely coordinated with the Tropical Ocean and Global Atmosphere and World Ocean Circulation Experiment seagoing measurement programs sponsored by the World Climate Research Programme. The satellite data, together with TOGA and WOCE measurements, will be analyzed by an international scientific team. This team will develop and refine computer models of the global ocean that can be used to investigate natural climate variability and assess the impact of human activities on climate—laying the groundwork for forecasts of future climate change.

FROM ANTIQUITY TO THE SPACE AGE

The mystery and power of the seas have always drawn us to voyage across them—to explore, to understand, and to take the measure of the Ocean Planet. This timeless and universal need to define ourselves and our world is now being reshaped by the Space Age.

Early Oceanographers

Navigational needs prompted the first attempts to measure the speed and course of ocean currents. Fragmentary records of tidal and current patterns along the Red Sea and Mediterranean coasts, compiled by early sailors and traders as an aid to commerce, have come down to us from antiquity. Driven by necessity, these intrepid seafarers were the first oceanographers.

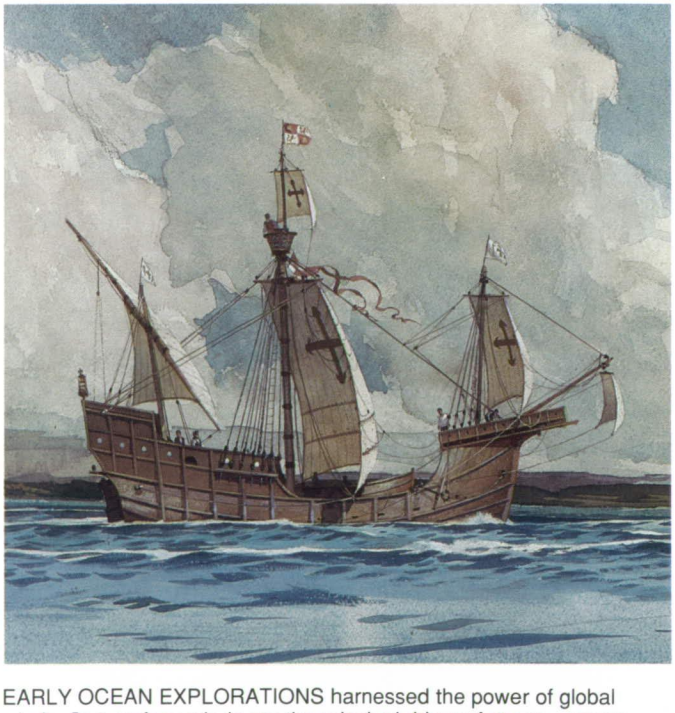
Viking expeditions crossed the North Atlantic, reaching Vinland (Labrador) around the year 1000. However, tales of a New World across the sea remained locked in Nordic lore. But early in the Renaissance, other Europeans began to fan out across the world's oceans in search of riches and new lands. By 1600, Portuguese, Spanish, French, and English expeditions had mapped most of the oceans and continents upon a globe that, in Europe, had lain half unknown scarcely a century before. These bold adventurers, bridging the Old World and the New, initiated the systematic exploration of the seas and revealed the dimensions of the Ocean Planet.

Beginnings of Research

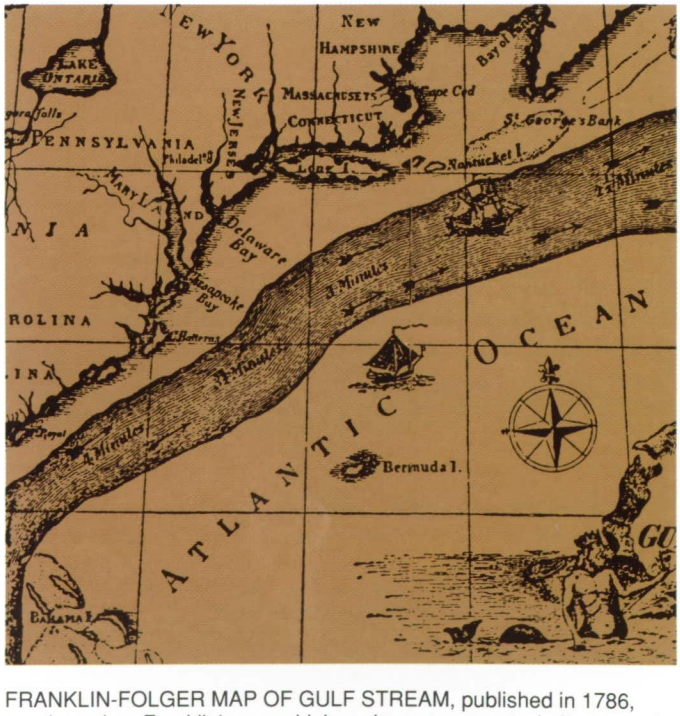
As Deputy Postmaster General for the American colonies, Benjamin Franklin sought to shorten the London-New York shipping time by charting Atlantic Ocean currents. In 1775, while sailing from London to Philadelphia, Franklin delineated the edges of the warm Gulf Stream through water-temperature measurements; his later map, constructed with the help of Nantucket sea captain Timothy Folger, is a classic of oceanography. The first office dedicated to ocean mapping had been established in France only five years earlier.

Shortly afterward, the English captain James Cook carried out his famous voyage to explore and chart the Pacific (1776-1779). Marine expeditions quickly multiplied. In 1849, drawing upon data collected from ships' logs, American naval officer M.F. Maury published the first worldwide wind and current charts.

The year 1872 marked the beginning of the first purely scientific oceanography expedition: the 42-month voyage of H.M.S. *Challenger,* sponsored by the British Royal Society. Covering 113,000 km (70,000 miles), *Challenger* systematically surveyed the deep ocean, collecting data on ocean depth, temperature, currents, and other properties. These revelations were organized and compiled over the following 20 years to lay the foundations of modern oceanography.



EARLY OCEAN EXPLORATIONS harnessed the power of global winds. Sea-surface winds are the principal driver of ocean currents, which also helped to determine the courses of such expeditions.



FRANKLIN-FOLGER MAP OF GULF STREAM, published in 1786, was based on Franklin's own shipboard measurements. In its general features, it agrees surprisingly well with satellite maps of the current.

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Oceanography Matures

The 20th century has seen major advances in oceanographic theory and technology, the widespread deployment of instruments in the sea, international scientific collaborations—and a host of new findings.

The beginning of the century (1900-1930) extended the studies of *Challenger,* particularly through the work of analogous national survey expeditions. Highlights include invention of the first reliable surface-to-bottom sampling bottle, development of the theory of wind-driven currents, and completion of the first trans-Atlantic physical, chemical, and biological measurements.

The period 1930-1960 saw rapid technical progress, intensive testing of theories of oceanic processes, and the first global research collaborations. Highlights include use of efficient new instruments for measuring temperature and tracking deep currents, models of large-scale ocean circulation, and recognition of the importance of eddies in global ocean circulation.

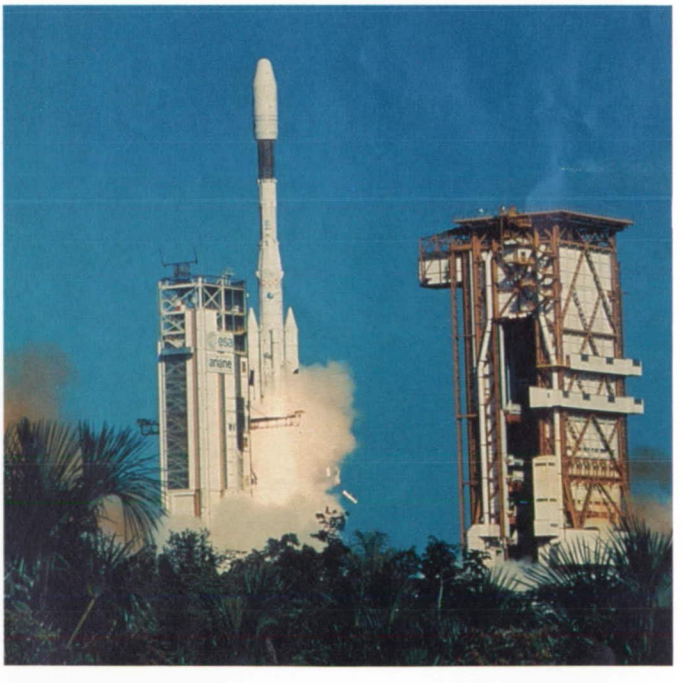
The last three decades (1960-present) have seen dramatic strides in ocean-measurement and computing technology, detailed regional studies, and a growing appreciation of the role of the oceans in climate. Highlights include the Indian Ocean Expedition, mooring of deep-ocean current meters, computer models of global oceanic and atmospheric circulation, the International Decade of Ocean Exploration, the beginnings of satellite oceanography, and the start of TOGA and WOCE. Most importantly, scientists have recognized the necessity of studying the Earth as a unified system of coupled components: land, oceans, atmosphere, and biosphere.

The Space Age

The beginning of the Space Age in 1957 heralded a technological revolution in Earth studies. In 1960, a U.S. weather satellite returned the first images of the Earth's cloud cover. By the 1970s, satellites were routinely gathering information on the physics, chemistry, and dynamics of the atmosphere and features of the land surface. The 1970s also saw the first use of satellite altimetry for measurements of sea-surface height.

Measurements carried out by ships and by instruments deployed in the sea are essential for research. However, these techniques are limited in both duration and geographic coverage; they cannot provide an understanding of global ocean circulation, which requires frequent, long-term observations of currents over ocean-basin scales. The measurement of ocean topography by satellite radar is the only way to obtain these observations. The promise of two decades of progress in radar altimetry from space will be fulfilled by the launch of TOPEX/POSEIDON in 1992.

INSTRUMENTED BUOYS permit extended, unattended ocean measurements. The deployment of instruments in the deep ocean far offshore was a major 20th-century research innovation.



ARIANE EXPENDABLE LAUNCH VEHICLE developed by the European Space Agency is being provided by France for the mid-1992 launch of TOPEX/POSEIDON from Kourou, French Guiana.

THE OCEAN-CLIMATE CONNECTION

What drives ocean currents? What controls their movement? How much heat do they distribute around the globe? Are ocean processes coupled to climate? These questions take us to the heart of the TOPEX/POSEIDON mission and the ocean-climate connection.

Both the oceans and the atmosphere transport roughly equal amounts of heat from the Earth's equatorial regions—which are intensely heated by the Sun—toward the icy poles, which receive relatively little solar radiation. The atmosphere transports heat through a complex, worldwide pattern of winds; blowing across the sea surface, these winds drive corresponding patterns of ocean currents. But the ocean currents move more slowly than the winds and have a much higher heat storage capacity. Like a massive flywheel that regulates the speed of an engine, the vast amount of heat stored in the oceans regulates the temperature of the Earth. The oceans are the thermal memory of the climate system.

Ocean Circulation

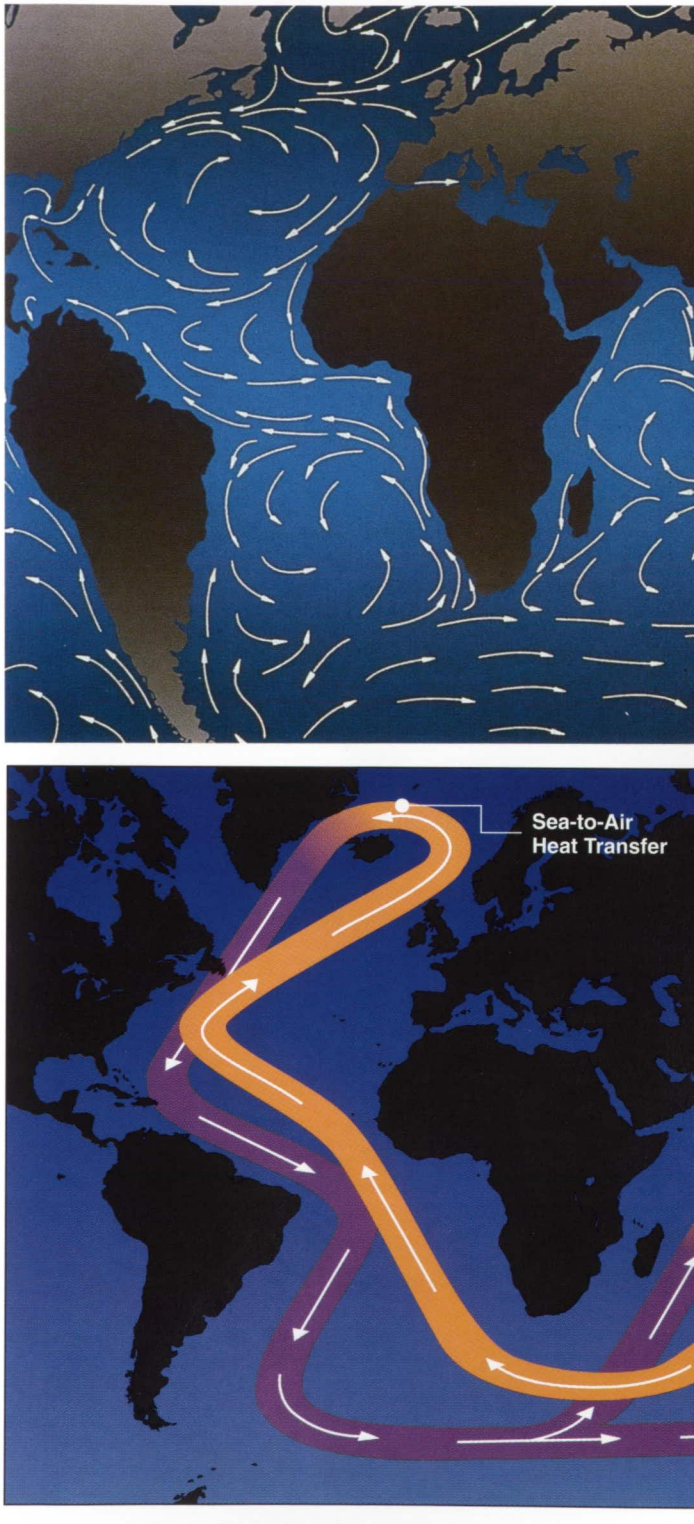
Atmospheric winds sweep the ocean surface layer along with them, raising sea-level height downwind. The surface of the tropical Pacific Ocean, for example, is normally piled about 50 cm (20 inches) higher off Asia than off South America because of the steady westward sweep of the tropical trade winds.

The ocean also responds to the Earth's rotation. Ocean currents are deflected to the right (in the Northern Hemisphere) or to the left (in the Southern Hemisphere) by the "Coriolis force," a rotational effect first explained by the French mathematician Gaspard Gustave de Coriolis (1792-1843). Driven by the winds and directed by the Coriolis effect, ocean surface currents circulate in enormous "gyres" around regions of raised or lowered sea level—the hills and valleys of ocean topography—just as winds blow around the extensive highs and lows of atmospheric surface pressure. Observations of ocean topography, together with our knowledge of the Coriolis force, thus permit the speed and direction of surface currents to be calculated.

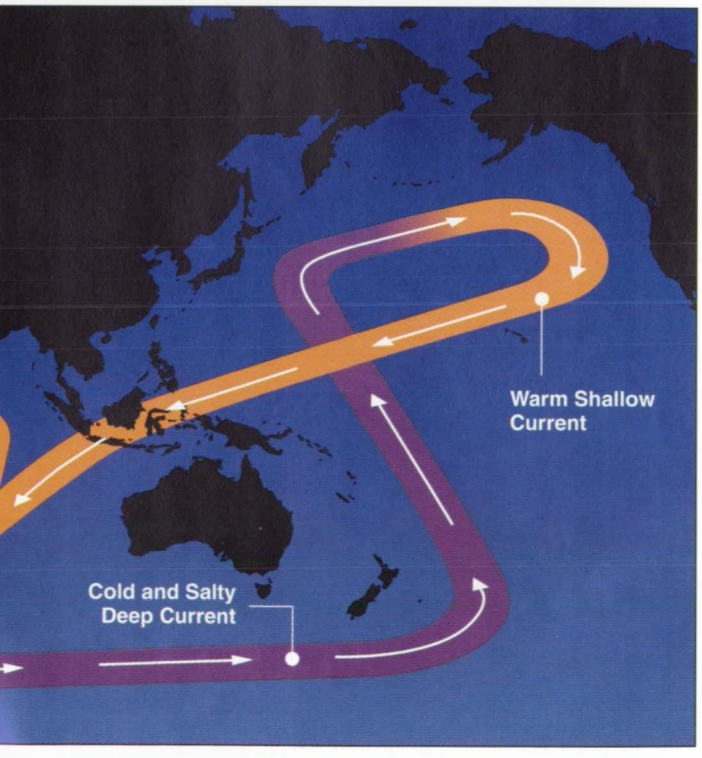
A Global Conveyor Belt for Heat

Along the western margins of the oceans, swift and narrow currents carry warm tropical surface waters toward the polar seas, where they lose heat to the atmosphere and then sink into the ocean depths. This sinking is most pronounced in the North Atlantic Ocean. Migrating back toward the Southern Hemisphere above the sea floor, the cold water eventually wells up to the surface layers of the Indian and Pacific oceans. This massive, global circuit takes almost 1,000 years.

The steady oceanic transport of tropical heat to the cold polar seas moderates our climate. Without the warming effect of the Gulf Stream, for example, the



GLOBAL PATTERNS OF OCEAN CIRCULATION *(top)* are shown schematically on this world map. The pattern is dominated by gyres that cover an entire ocean basin; these circulate clockwise in the Northern Hemisphere, counterclockwise in the Southern Hemisphere.



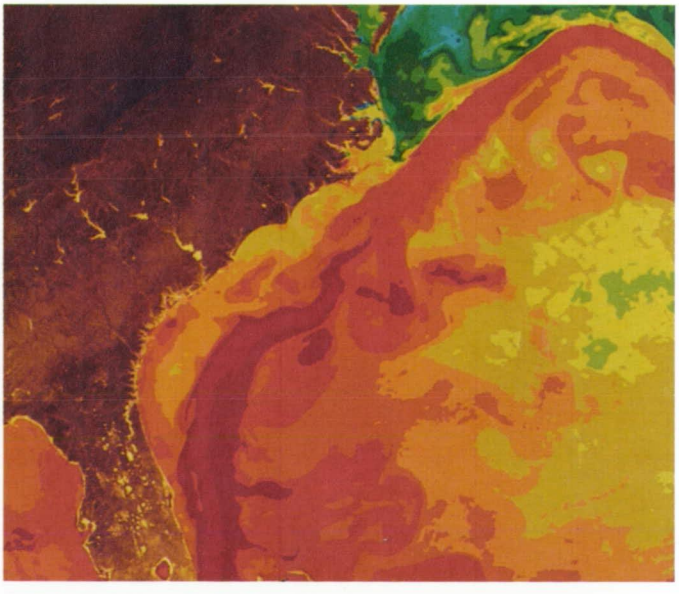
GLOBAL CONVEYOR BELT FOR HEAT *(bottom)* transports warm surface waters *(orange)* into the North Atlantic, where they cool, sink, and then move southward *(purple)* throughout the depths of the global oceans—upwelling after 1,000 years back to the surface.

climate of Europe would resemble that of northern Canada. Conversely, human activities have the potential to influence this circulation pattern and thus alter our climate.

Climate Change

The oceans also regulate climate by absorbing carbon dioxide and other greenhouse gases. Analysis of ocean carbonate sediments and polar ice-cap deposits shows that atmospheric composition and ocean circulation have both varied dramatically in the past: 18,000 years ago, during the last Ice Age, carbon-dioxide levels were 40 percent below those of today and sea level stood more than 100 m (330 feet) lower. A better understanding of ocean processes is needed to interpret this history and to forecast long-term climate trends.

The oceans play a role in short-term climate shifts as well. At intervals of three to seven years, the weakening of tropical trade winds allows warm Asian surface waters to surge eastward across the Pacific to South America. Accompanied by major shifts in atmospheric circulation and rainfall, these "El Niño" events disturb climate worldwide. The El Niño of 1982-83, the worst of this century, triggered flooding and landslides that claimed 600 lives in Ecuador and Peru and devastated the U.S. West Coast; cyclones left 25,000 homeless in Tahiti, and severe droughts struck Australia, Indonesia, the Philippines, and South Africa. Improved knowledge of upper-ocean circulation in the tropical Pacific is essential for the reliable prediction of such events.



THE MIGHTY GULF STREAM, bearing warm water along the U.S. East Coast toward Europe, stands out *(red)* in this temperature-sensitive image from space. Huge eddies, spun off from the stream, carry energy far out into the Atlantic; they may last for a year or more.

THE OCEAN DECADE

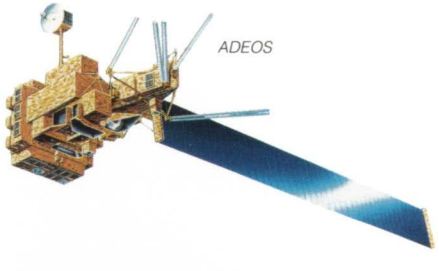
How do ocean-atmosphere interactions shape El Niño climate events? What is the global pattern of ocean circulation? What additional observations from space are required? These questions are now being addressed through an international, coordinated research effort, including NASA's Mission to Planet Earth. During the decade of the 1990s, oceanography involving seagoing field experiments and space missions is being intensified. TOPEX/POSEIDON is a core element of this research.

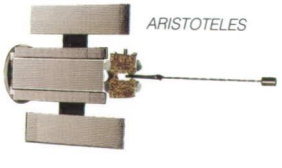
TOGA

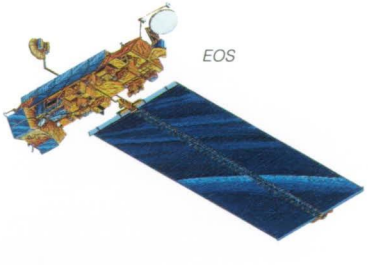
The international Tropical Ocean and Global Atmosphere (TOGA) program was begun by the World Climate Research Programme (WCRP) in 1985 to study the year-to-year variability of the tropical oceans and their coupling to the global atmosphere. This decade-long effort involves extensive observations and modeling studies. The results will help to improve the predicability of ocean-atmosphere interactions on timescales ranging from months to years—particularly El Niño events in the Pacific Ocean.

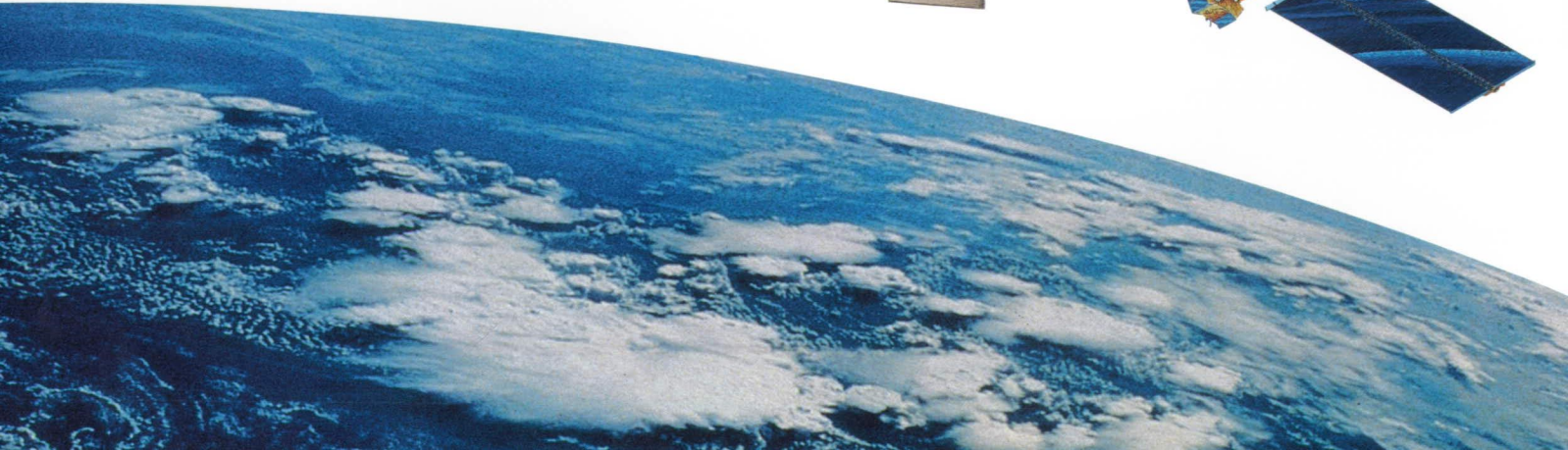
DAMAGE FROM EL NIÑO CLIMATE EVENTS is a recurrent threat to coastal communities. The effects of these disturbances are also felt far inland through floods, droughts, and shifts in rainfall patterns.

During the flight of TOPEX/POSEIDON, an intensive TOGA field program will study the warm-water pool in the western tropical Pacific—the Earth's largest reservoir of warm surface water—and its role in the El Niño phenomenon. The altimeter measurements of sea-level height will provide a Pacific-wide perspective on this field study. Conversely, the TOGA measurements will help to validate the observations from space.

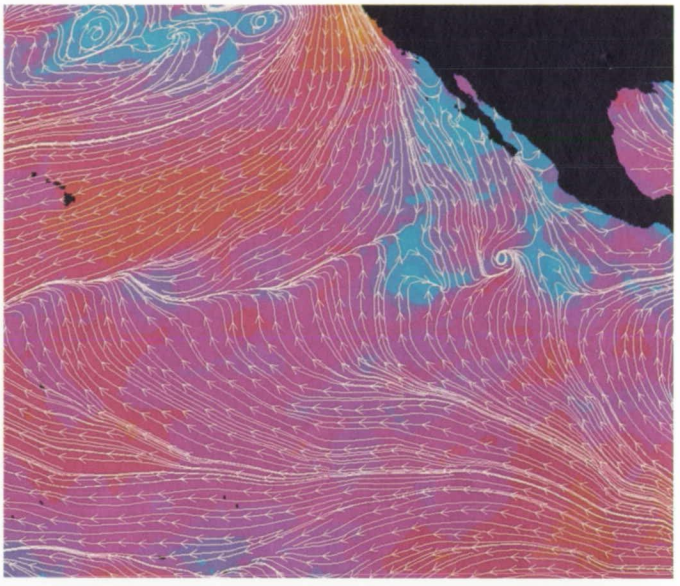








DIRECT MEASUREMENTS OF OCEAN CURRENTS will continue to be essential. Data from shipboard and moored instruments are needed for regional studies and the validation of space observations.



PACIFIC TRADE WIND FIELD was calculated from 1978 Seasat scatterometer data. Surface winds are drivers of heat-transporting ocean currents, which play a key role in disruptive El Niño events.

WOCE

The World Ocean Circulation Experiment (WOCE) was begun by WCRP in 1990 to better describe and understand global ocean circulation and its relationship to climate changes over decades or longer. During the 1990s, scientists from 40 nations will carry out an unprecedented series of oceanographic observations and measurements through a worldwide network of sea-level stations and a fleet of research vessels covering all the oceans. The WOCE network will permit calibration of TOPEX/POSEIDON observations—which, in turn, will provide a global reference framework for the integration of the WOCE seagoing measurements.

WOCE will provide the data necessary to make major improvements in the accuracy of computer models of ocean circulation. As these models become more precise, they will be coupled to models of atmospheric circulation to simulate—and ultimately to help predict—how the ocean and the atmosphere will together determine our future climate.

Space Missions

TOPEX/POSEIDON will be complemented by other important space missions over the next decade. The multipurpose European Remote-sensing Satellite (ERS-1) satellite, launched in 1991, carries a radar altimeter together with five other instruments. Although its altimetric measurements are less accurate than those of TOPEX/POSEIDON, its high-latitude coverage allows ERS-1 to study polar ocean and ice topography inaccessible to the U.S./France mission. The two missions are complementary: their altimeter data will be merged to yield a single data set of greater coverage than either can provide alone.

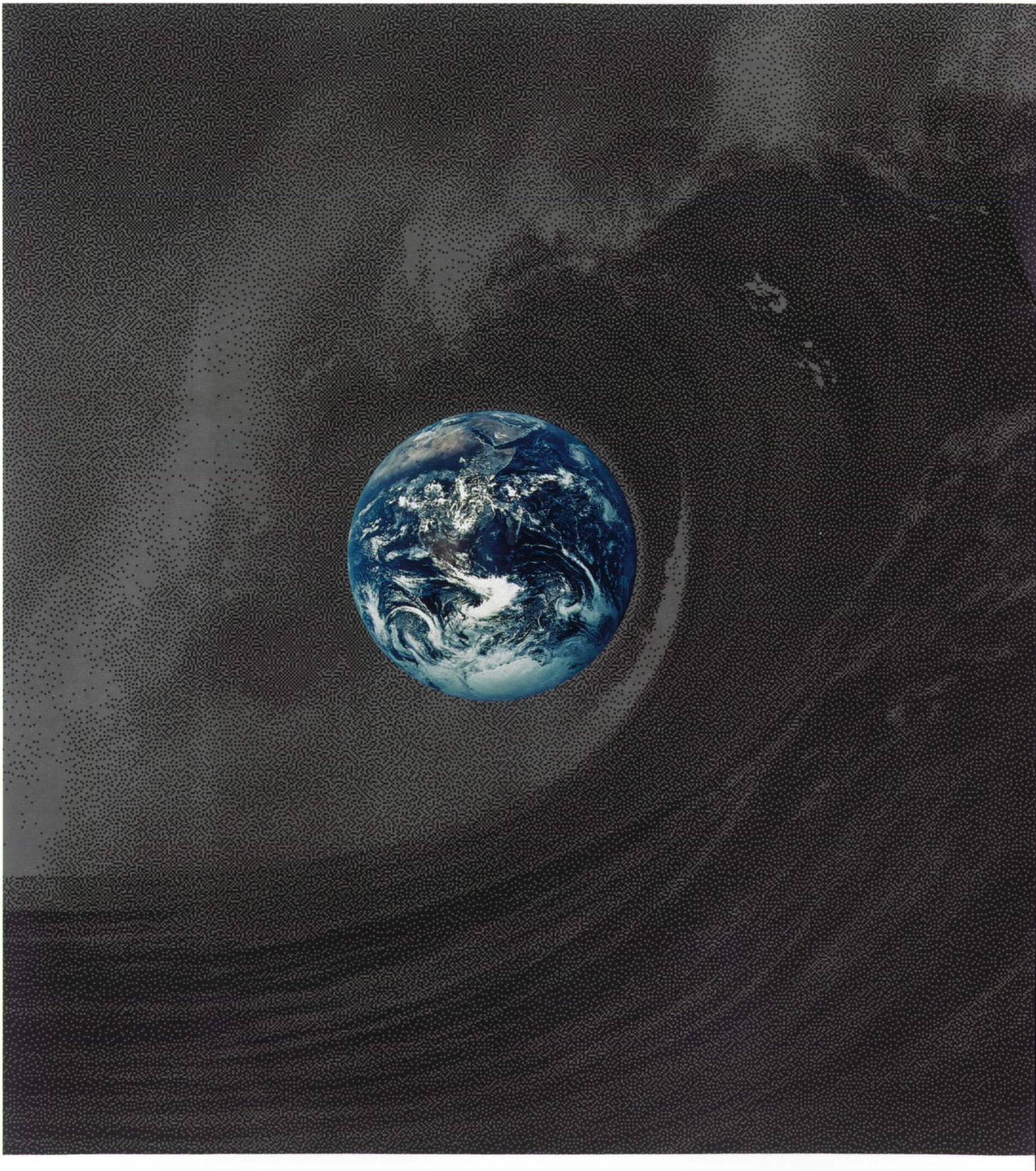
The NASA Scatterometer (NSCAT), to be flown on the Japanese Advanced Earth Observing Satellite (ADEOS) in 1996, will measure the speed and direction of sea-surface winds with high accuracy over 95 percent of the global ocean every two days. The potential overlap of the TOPEX/POSEIDON and NSCAT missions provides an exciting opportunity to study the ocean's response to wind forcing.

The ARISTOTELES gravity-measurement satellite being considered by the European Space Agency (ESA) for flight in the late 1990s would carry a gravity gradiometer to measure in detail the spatial variations of the Earth's gravity field. These data would greatly improve the accuracy of ocean-circulation calculations.

The Earth Observing System (EOS) is a series of satellites that will be a central component of Mission to Planet Earth beginning in the late 1990s. EOS will provide long-term (15-year) data sets to further our understanding of the interactions among the Earth's land surfaces, oceans, atmosphere, and biosphere, and how these are being influenced by human activities. As well as providing new data on the global hydrologic and biogeochemical cycles, EOS will extend altimetric measurements of global ocean circulation into the next century.

...how many new beauties do not now begin to present themselves in the machinery of the ocean! ...its great heart not only beating time to the seasons, but palpitating also to the winds and the rains, to the clouds and the sunshine, to day and night.

M. F. Maury, *Physical Geography of the Sea*, 1855



A GLOBAL VIEW FROM SPACE

Oceanography is no longer tethered to the sea. Satellite technology has now enabled scientists to place sensitive sensors in space, far above the sea surface, to take a new measure of the Ocean Planet.

Two Decades of Progress

Although an experimental radar altimeter was flown in 1973 aboard NASA's Skylab mission, NASA's Geophysical Satellite-3 (Geos-3, 1975-1978) carried the first instrument to yield useful measurements of sea level and its variability with time. The Geos-3 map of Gulf Stream variability was in good agreement with historical ship observations.

NASA's 1978 Seasat carried the first altimeter designed for oceanography and returned the first global sea-surface measurements. Although the mission operated for only 100 days, it collected more ocean-topography data than the previous 100 years of shipboard research. An altimeter on the U.S. Navy's Geodetic Satellite (Geosat, 1985-1989) gathered the first multiyear global data set on sea-level height, producing the most accurate variability measurements yet obtained.

The pioneering Geos-3, Seasat, and Geosat missions reflect two decades of progress in instrument technology and scientific analysis. Improvements in altimetric precision reduced the uncertainty in satellite height above the sea surface from Skylab's 60 cm (24 inches) to Geosat's 4 cm (1.6 inches). However, all were limited by uncertainties in the satellite orbit, which ranged up to 10 m (33 feet) for Geos-3 and up to 2 m (6.6 feet) for Seasat and Geosat. Consequently, these missions could not provide definitive studies of ocean circulation, which require topographic measurements with an error of 14 cm (6 inches) or less across an entire ocean basin.

TOPEX/POSEIDON: Meeting the Challenge

TOPEX/POSEIDON is the first mission designed to bring both high altimetric precision and high orbital accuracy to bear upon the challenge of ocean topographic mapping. It will provide a detailed, global snapshot of the ocean surface every 10 days over a period of three to five years.

A high orbital altitude of 1,336 km (830 miles), chosen to minimize atmospheric drag and the effect of spatial variations in the Earth's gravity, will permit TOPEX/POSEIDON to be tracked with unprecedented accuracy. The orbital inclination will carry the spacecraft to 66 degrees north and south latitude, allowing a thorough sampling of tidal signals. The satellite's measurement tracks across the Earth will be reproduced within 1 km (0.6 mile) over every 10-day repeat cycle, so that the altimeters can repeatedly measure nearly identical points on the sea surface. The widest spacing between tracks, at the equator, will be only 315 km (195 miles).

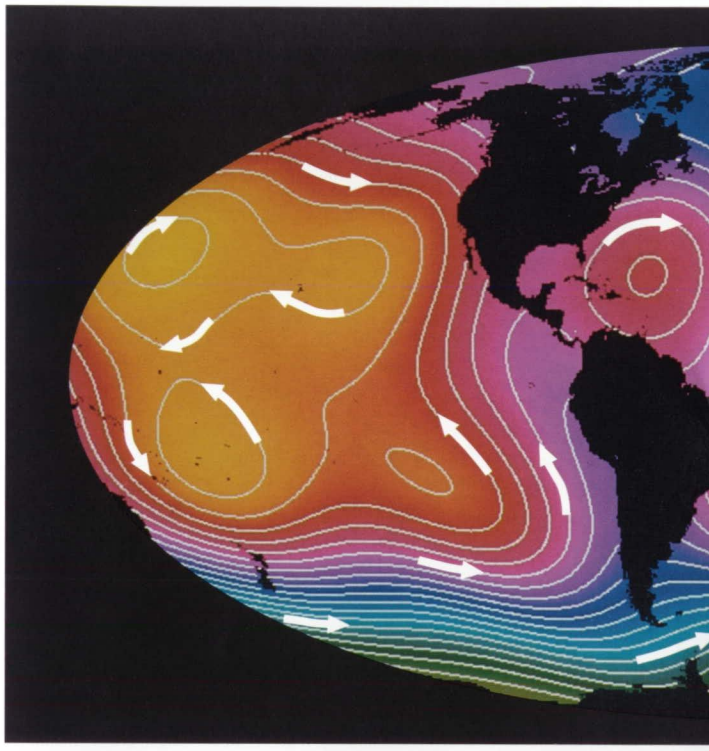
MAPPING THE OCEAN SURFACE

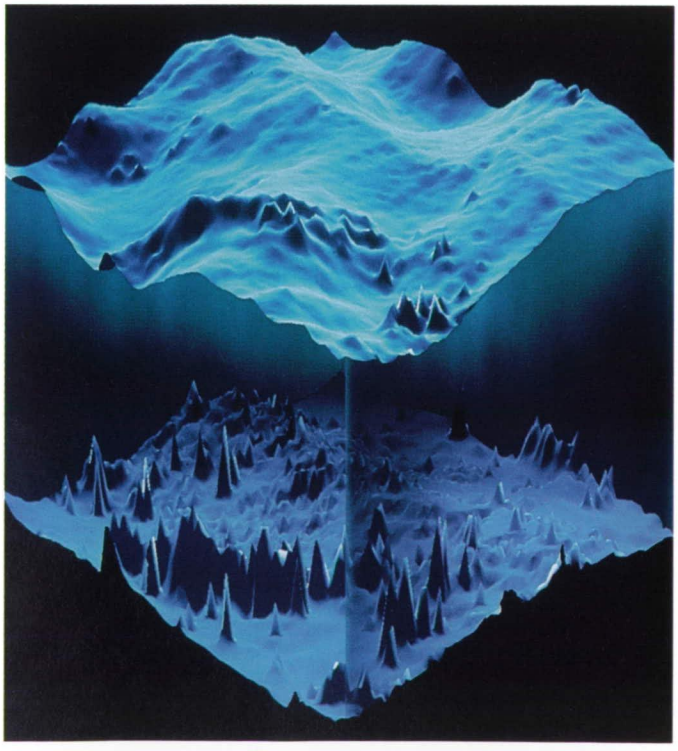
What determines the shape of the ocean surface? How is this shape measured from space? How can we minimize the uncertainty of this measurement? The answers to these questions draw upon fundamental physics, advanced technology, and the inspired perseverance of a generation of satellite oceanographers.

Static Gravity, Dynamic Oceans

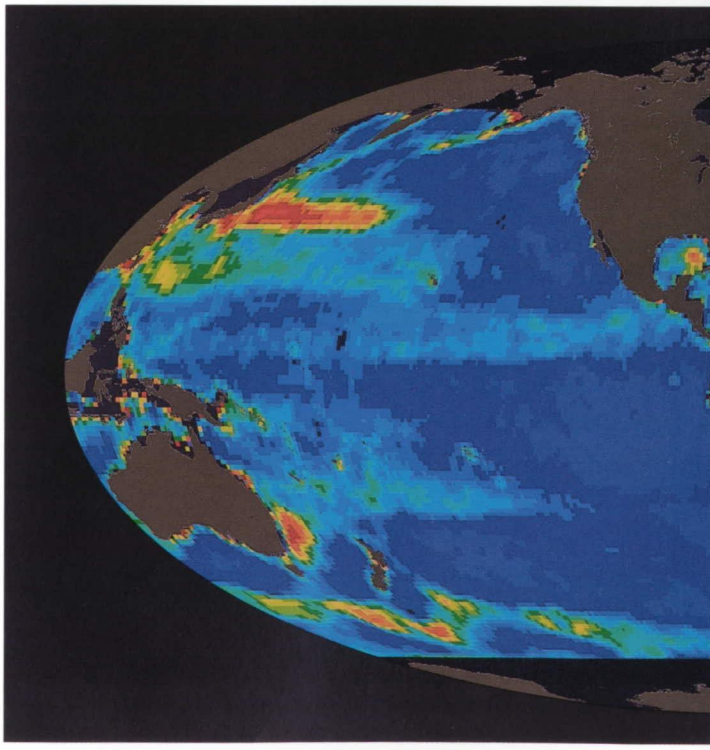
If the ocean were motionless, the shape of its surface would be determined entirely by the gravitational attraction of the Earth. Even in that case, however, the sea surface would have hills and valleys. Because matter is distributed unevenly within the Earth's crust—densely packed within mountain ranges, thinned by valleys—the Earth's gravity field varies substantially over both the continents and the seas. This spatial variation of gravity itself generates sea-surface topography with a global altitude range of nearly 160 m (525 feet) relative to the center of the Earth.

Swept by winds and seething with waves, the ocean is actually in ceaseless motion, flowing in gigantic currents and gyres directed by the Coriolis effect of the Earth's rotation. The shape of the sea surface is dynamic, and it therefore departs from the static topography

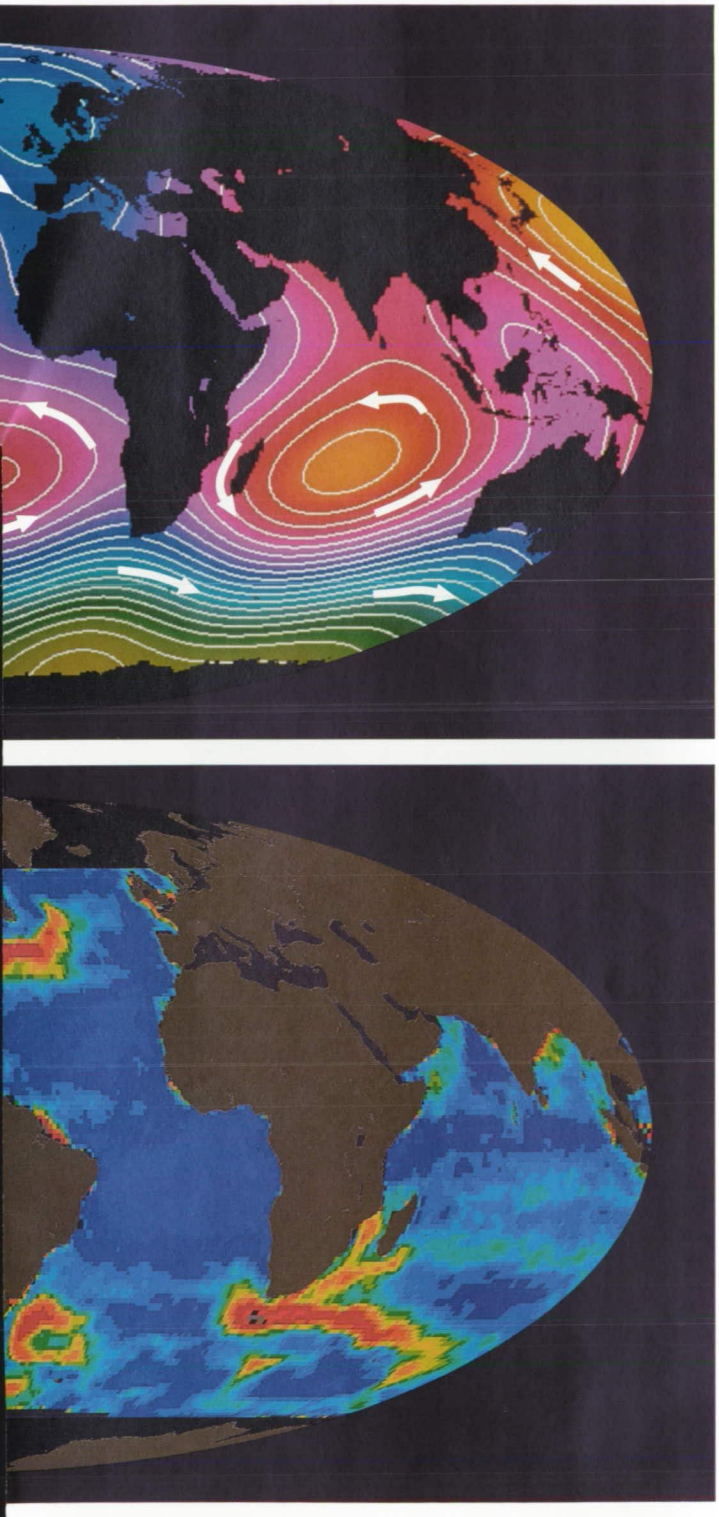




INFLUENCE OF GRAVITY ON OCEAN TOPOGRAPHY is schematically illustrated in this comparison of sea level with the shape of the ocean floor *(vertical scales exaggerated)*. In the absence of currents, sea-surface topography tends to follow ocean-bottom contours.



DYNAMIC TOPOGRAPHY OF THE GLOBAL OCEAN *(top)* was determined from two months of Geosat altimetry data. Ocean currents circulate *(arrows)* around this global system of tropical highs *(red)* and polar lows *(blue)*. TOPEX/POSEIDON will provide much more detail.



VARIABILITY OF OCEAN CIRCULATION *(bottom)* is revealed by repeated Geosat altimetric measurements over the same position on the ocean surface. Highest variability *(red, yellow)*, associated with swift boundary currents, is found off the east coasts of the continents.

determined by gravity alone. This departure, called *dynamic ocean topography,* has a global range in altitude of about 2 m (6.6 feet)—barely one percent of the altitude range of the gravitational topography. But only the dynamic topography contains information about the speed and direction of ocean currents. The challenge is to measure this slight topographic variability over the vast dimensions of the ocean basins.

How Altimetry Works

Dynamic ocean topography is mapped through a three-step process: (1) The radar altimeter sends short pulses of microwave energy toward the ocean below; the round-trip travel times of the reflected pulses yield the distance between the spacecraft and the sea surface. (In addition, the shape of the reflected pulse is used to determine wave height and sea-surface wind speed.) (2) A precise determination of the satellite orbit then permits these distance measurements to be translated into a global map of sea level relative to the center of the Earth. (3) Finally, the map of sea-surface topography is compared with a map of gravitational topography, which must be obtained independently; the difference between the two is dynamic ocean topography, from which ocean-current velocities can be calculated.

Step (1) requires careful correction for atmospheric effects. Water vapor absorbs microwave radiation and delays the radar pulses during their round trip to the sea surface. Following the example of Seasat, TOPEX/POSEIDON therefore carries a microwave radiometer for concurrent measurements of atmospheric water-vapor concentrations; the water-vapor effect can then be calculated and eliminated from the data.

Electrons released by the ionization of gases in the upper atmosphere (ionosphere) by sunlight also introduce a pulse-arrival delay. Because this delay depends on the radar frequency, observations at two different frequencies permit correction for this effect as well.

The most important uncertainty, however, enters at step (2): determination of the satellite's orbital altitude. TOPEX/POSEIDON will therefore be tracked with unprecedented accuracy by three independent and complementary systems.

The Tides

Regular sea-level oscillations caused by the tides present another challenge to accurate topographic measurements. However, the TOPEX/POSEIDON orbit has been chosen to permit separation of the primary lunar and solar tidal signals from the dynamic ocean topography, so that tidal effects can be eliminated from the ocean-circulation calculations. TOPEX/POSEIDON will in fact provide the observations needed to compute definitive global tide models, which can then be applied to data from all future oceanographic missions.

INSTRUMENTS: UNPRECEDENTED ACCURACY

The TOPEX/POSEIDON spacecraft, constructed by the Fairchild Space Company, is a modification of the Multimission Modular Spacecraft (MMS) used for NASA's 1980 Solar Maximum Mission and the later Landsat-4 and -5 missions. The 2,400-kg (5,300-lb) satellite carries a suite of six instruments, provided by the United States and France, housed in a special instrument module attached to the MMS satellite bus. Power is supplied by a single large solar-cell array.

In addition to the dish-shaped antenna used for radar altimetry, the spacecraft has a variety of communications antennas to link the mission with the NASA Tracking and Data Relay Satellite System (TDRSS), the CNES Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) tracking system, and the U.S. Global Positioning System (GPS) of high-altitude navigational satellites.

Two Altimeters

The primary instrument is the NASA dual-frequency TOPEX altimeter, operating at 5.3 and 13.6 GHz, which draws upon a long heritage of single-frequency instruments extending back to Seasat. Dual-frequency operation permits correction for the ionospheric-electron delay effect. This instrument, managed by NASA's Goddard Space Flight Center (GSFC) and built by The Johns Hopkins University's Applied Physics Laboratory (JHU/APL), is fully redundant and incorporates well understood, flight-tested technology.

The companion TOPEX microwave radiometer, developed by NASA's Jet Propulsion Laboratory (JPL), operates at frequencies of 18, 21, and 37 GHz to provide estimates of total atmospheric water-vapor content. The 21-GHz channel is the primary measurement channel; the 18-GHz and 37-GHz channels are used to remove the effects of wind speed and cloud cover, respectively. These data allow reduction of the water-vapor delay error to 1 cm (0.4 inch), permitting an overall altimetric precision of 3 cm (1.2 inches).

The mission also carries an advanced, experimental solid-state POSEIDON altimeter, designed by CNES and built by Alcatel Espace, which uses the same antenna as the NASA altimeter but operates at a single frequency of 13.6 GHz. The ionospheric-electron correction is provided by a model that makes use of the simultaneous dual-frequency measurements of the DORIS tracking system.

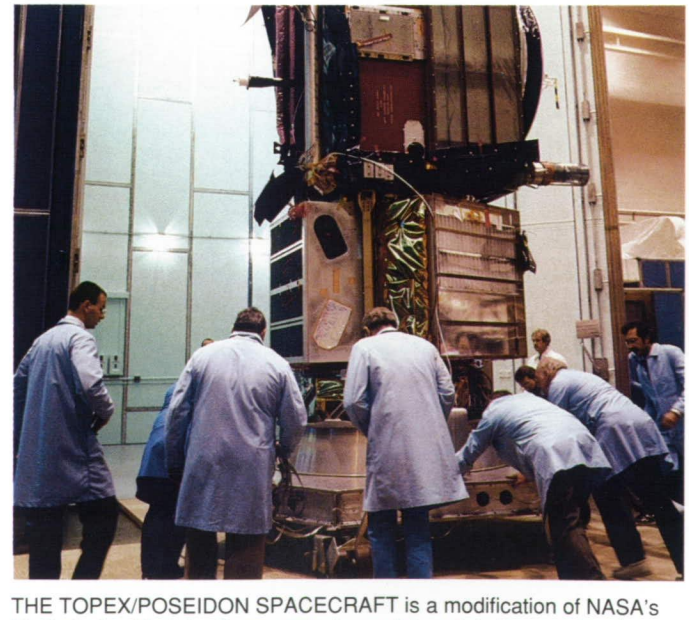
Both the operating principles and the expected performance of the two altimeters are similar. However, the single-frequency POSEIDON altimeter has only one-fourth the mass, volume, and power consumption of the NASA instrument. Moreover, the telemetry data rate is reduced by a factor of 7 because of more extensive on-board processing. The CNES instrument is thus a prototype for the satellite altimeters of the future.

Three Tracking Systems

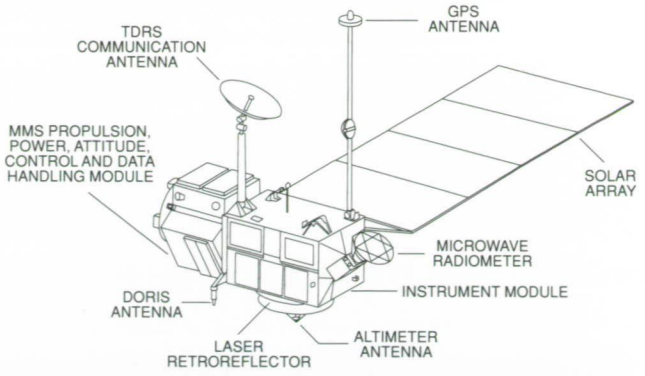
The NASA tracking system, managed by GSFC, operates by laser ranging to reflectors (built by JHU/APL) arrayed around the altimeter antenna, which permit the satellite to be intermittently tracked by a worldwide, ground-based network of 12 laser stations within about 2 cm (less than 1 inch). These data will be used with computer models of the Earth's global gravity field (developed at GSFC, at the University of Texas at Austin, and in France) for precision orbit determination and calibration of the altimeters.

The DORIS system determines the satellite's velocity by measuring the Doppler shifts of two ultrastable microwave frequencies (2,036 MHz and 401 MHz) transmitted by a global network of some 50 ground-based beacons whose positions are known within a few centimeters (several inches). Validated by a prototype receiver launched in 1990 on the French SPOT-2 Earth-observing mission, DORIS has already provided more than two million measurements; these have been used to refine data-processing methods and improve gravity models. DORIS is manufactured under CNES management by Dassault Electronique (receiver), CEIS Espace (beacons), and CEPE and OSA (quartz oscillators).

The mission also carries an experimental GPS receiver, developed by Motorola under contract to JPL, in order to demonstrate GPS capabilities. The GPS system provides continuous spacecraft tracking with a potential accuracy of 10 cm (4 inches) or better and promises to revolutionize orbit determination for future satellites.

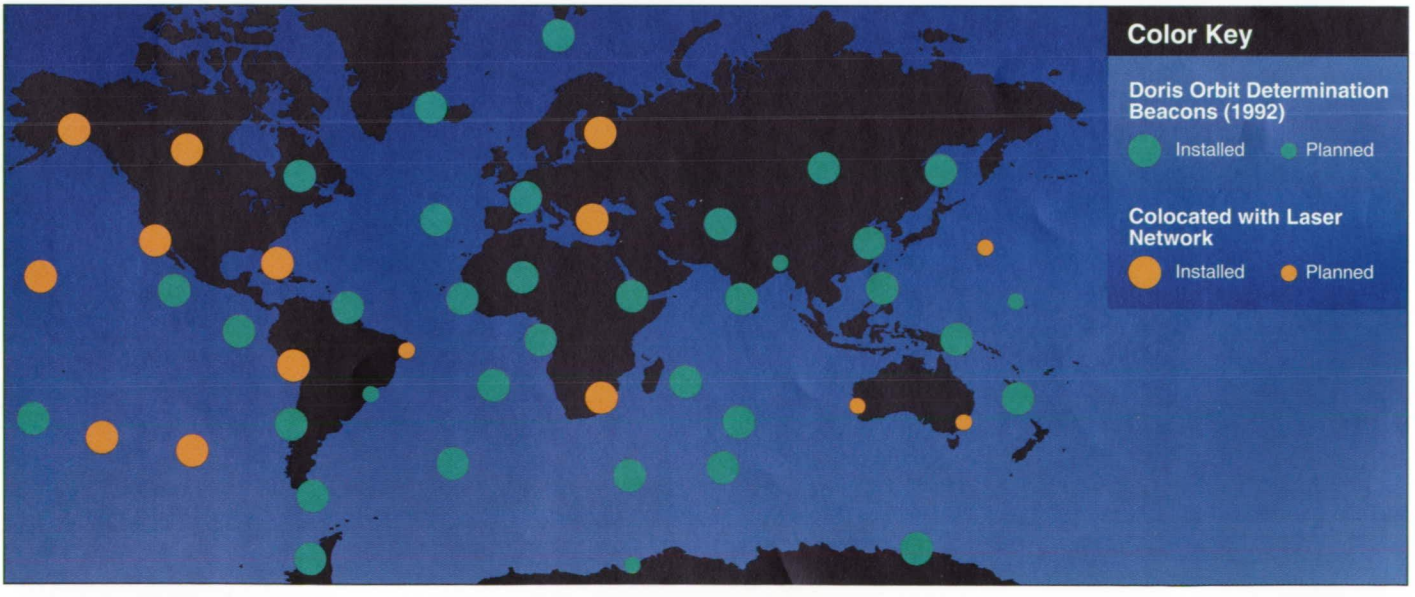


THE TOPEX/POSEIDON SPACECRAFT is a modification of NASA's Multimission Modular Spacecraft. A special module houses the six instruments contributed by the United States and France.



TOPEX/POSEIDON Instrument Characteristics

Instrument	Measurement/Purpose	Frequency	Accuracy	Mass	Power
Dual-Frequency TOPEX Altimeter	Height of satellite above the sea, wind speed, wave height, ionospheric correction.	13.6 GHz 5.3 GHz	2.4 cm altitude	206 kg	237 W
TOPEX Microwave Radiometer	Total water vapor along the path viewed by the altimeter; this measure corrects altimeter data for pulse delay due to water vapor.	18.0 GHz 21.0 GHz 37.0 GHz	0.2-g/cm^2 water-vapor density (equivalent to 1.2 cm)	50 kg	25 W
Laser Retroreflector Array	Used with ground-based lasers to track the satellite and to verify satellite height measurements.		2 cm overhead ranging	29 kg	
Single-Frequency POSEIDON Altimeter	Height of satellite above the sea, wind speed, wave height.	13.65 GHz	2.5 cm altitude	23 kg	49 W
DORIS Dual-Frequency System Receiver	Receives signal from ground stations for satellite tracking.	401.25 MHz 2036.25 MHz	5-10 cm altitude	43 kg	21 W
Global Positioning System Receiver	Provides a new tracking data type (range differences) for continuous precision orbit determination.	1227.6 MHz 1574.4 MHz	10 cm or better altitude	28 kg	29 W



NETWORKS OF GROUND-BASED TRACKING STATIONS will determine the position of the satellite within 10 cm (4 inches). The U.S. laser tracking system uses reflections of laser beams from the satellite to locate its position; the French DORIS system employs all-weather radio beacons. The U.S. Global Positioning System of high-altitude navigational satellites will also be used to demonstrate GPS tracking capabilities.

UNITED STATES/FRANCE PARTNERSHIP

The Jet Propulsion Laboratory in Pasadena, California is responsible for TOPEX/POSEIDON project management, including prelaunch mission planning, development of the U.S. sensors, design and development of the U.S. ground data system, and post-launch control and communication with the satellite. Within CNES, the Centre Spatial de Toulouse is responsible for participation in mission design and management, development of the French sensors and ground data system, and provision of the Ariane launch-vehicle system and launch services.

The mission schedule is divided into five phases: launch, assessment (35 days), initial verification (six months), observation (three years), and extended observation (two more years, with even longer operation possible).

Launch and Assessment

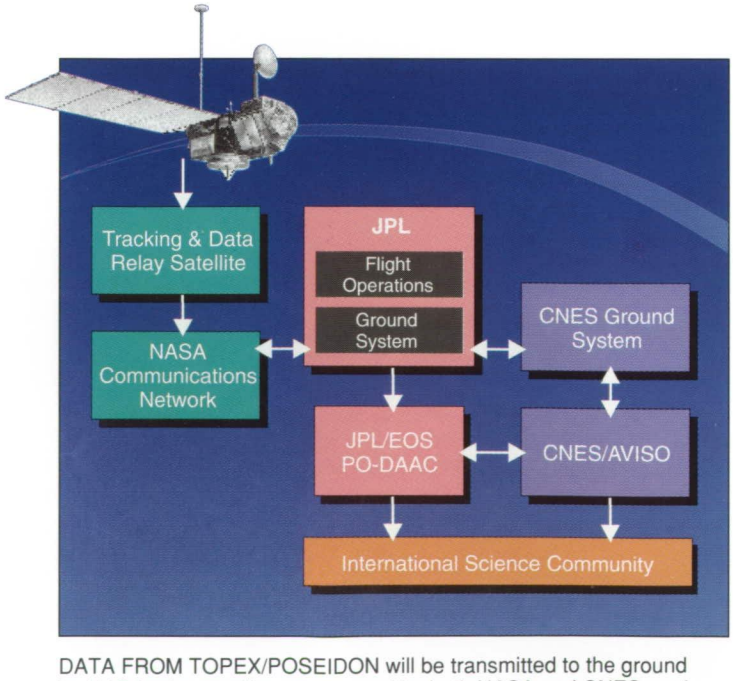
TOPEX/POSEIDON will be launched by an Ariane 42P expendable launch vehicle from the European Space Agency's Guiana Space Center in Kourou, French Guiana. JPL will conduct mission operations, data acquisition, and data processing; the Centre Spatial de Toulouse will process data from the CNES payload. The critically important assessment phase officially begins 18 minutes after launch with the separation of the satellite from Ariane and ends 35 days later. During this period, the satellite and sensor systems will be deployed, activated, and functionally certified, and the satellite will achieve its operational orbit.

Triple Tracking

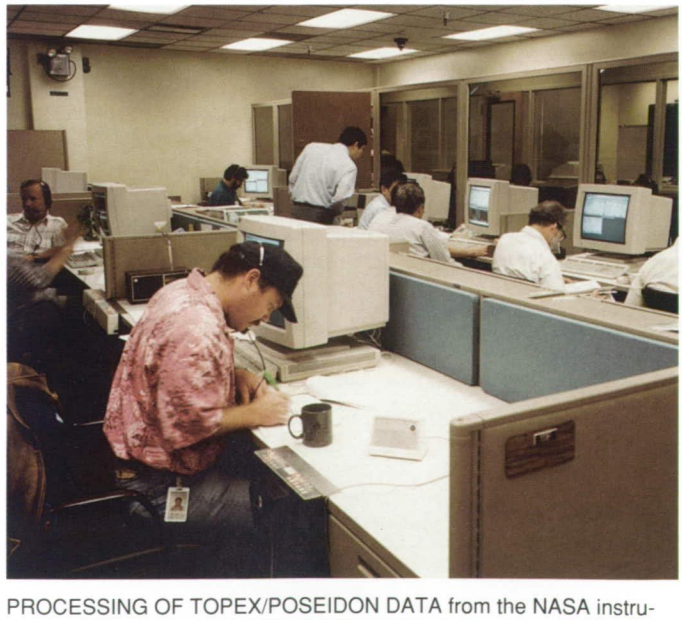
The NASA/GSFC laser-ranging system will furnish the baseline tracking data needed for precise orbit determination and verification of the altimeter measurements. However, the laser beams cannot penetrate cloud cover. The recently demonstrated CNES DORIS system, used in addition to the NASA system, will provide all-weather tracking through radio beacons to the onboard DORIS receiver. Since neither system provides constant coverage of the satellite, computer models of the Earth's gravity field will assist in high-precision orbit determination; TOPEX/POSEIDON tracking data will, in turn, help to provide still further improvements to these models. The GPS system will supplement the two primary tracking systems as a demonstration of its capability for continuous satellite tracking.

Instrument Verification

Verification of the performance of the satellite and its instruments is necessary to ensure the validity and integrity of the scientific data. Although this is a continuous task, an intensive verification campaign will be conducted jointly by NASA and CNES during the first six months of the mission to calibrate and verify the satellite data through comparison with measurements made at two specially chosen verification sites. This work will be carried out in parallel with additional, longer-term programs of data validation conducted through TOGA and WOCE.

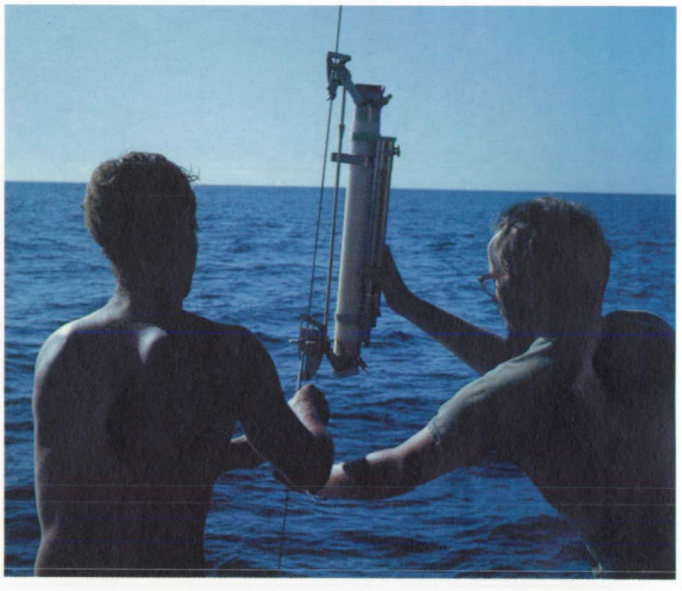


DATA FROM TOPEX/POSEIDON will be transmitted to the ground by NASA relay satellites, processed by both NASA and CNES, and archived in special data centers providing international access.



PROCESSING OF TOPEX/POSEIDON DATA from the NASA instruments will be carried out at the Jet Propulsion Laboratory, which holds primary mission-management responsibilities for NASA.

TIDE GAUGES will be used to make direct measurements of sea-level fluctuations at numerous remote island and coastal sites, necessary to verify TOPEX/POSEIDON observations from space.



NANSEN OCEAN SAMPLING BOTTLES invented by the Norwegian oceanographer Fridtjof Nansen in 1900 are still an indispensable tool for the sudy of deep-ocean physics, chemistry, and biology.

NASA Data Validation

JPL is instrumenting an oil-drilling platform, provided by Texaco Corporation, 12 km (7 miles) west of Point Conception, California, to obtain data on sea level and related parameters. Sea-level measurements will be made by an acoustical device and pressure gauges mounted on the platform. These data, together with data from nearby laser tracking sites, will be used to determine the distance from the satellite to the sea surface, which will then be compared with the altimeter ranging measurements to calibrate their performance. Other instruments will include a GPS receiver to measure total ionospheric electron content, together with a surface pressure gauge and an upward-looking radiometer to check the altimeter ranging correction.

CNES Data Validation

CNES is instrumenting two islands, Lampione and Lampedusa, in the Mediterranean Sea. The instrument configuration will include a laser, tidal gauges, deep-sea pressure gauges, a DORIS station, a radiometer, a meteorological station, and wind and wave buoys. These instruments will verify sea level, atmospheric pressure, wind speed, wave height, the water-vapor correction, orbit determination, and other sources of ocean-topography error. Ionospheric corrections will be verified by comparison of the DORIS and GPS measurements with those made by the NASA dual-frequency altimeter, as well as through data furnished independently by a European ground-based radar system.

Later Mission Phases

The observational phase begins at the completion of initial verification and extends until the nominal end of the mission, three years after launch. The priorities during this phase are the recording of observational data and maintenance of the scientific capability of the satellite. If good performance continues and funding is provided, the TOPEX/POSEIDON mission will be extended for an additional two years or more. The spacecraft will carry sufficient fuel for a full decade of operation.

Data Distribution and Archiving

The primary mission product is the Geophysical Data Record (GDR). During the initial verification phase, activity will focus on data validation; altimetry data will be processed into interim GDRs and distributed to the science team for study. By the end of this phase, all the geophysical measurements will be calibrated and verified, and the parameters necessary for the production of the final GDR will be approved.

The final GDR will be distributed both to the mission scientists and the broader scientific community. As the complete record of TOPEX/POSEIDON observations, the GDR will include sea-height measurements and all the corrections applied to them, as well as data on wave height, wind speed, and satellite altitude and location. Both interim and final GDRs will be available through NASA's EOS Physical Oceanography Distributed Active Archive Center (PO-DAAC) at JPL and the French data center, AVISO.

SCIENTIFIC UNDERSTANDING

Through the work of an international science team, the results of TOPEX/POSEIDON will be widely shared, analyzed, and interpreted to increase our knowledge of global ocean circulation and its role in climate change.

Selection and Role

When TOPEX/POSEIDON was still in its early planning stages, NASA and CNES selected thirty-eight scientists through a competitive Announcement of Opportunity to play leadership roles in the analysis and interpretation of mission data. They represent nine countries: sixteen are from the United States, thirteen are from France, and the remainder are from Japan, Australia, South Africa, Germany, Norway, the Netherlands, and the United Kingdom.

These men and women, together with their more than 160 research collaborators, form the TOPEX/POSEIDON science team, which holds primary responsibility for the achievement of mission science goals. However, the entire TOPEX/POSEIDON data set will be made available to the international scientific community to support additional investigations, opening a new spectrum of research efforts directed at an understanding of global climate change.

Science-Team Investigations

TOPEX/POSEIDON will return the first accurate topographic data on ocean-basin scales, permitting thorough investigations of circulation in the Pacific, Atlantic, Indian, and Southern oceans. When combined with the results of seagoing measurement programs, these data will also permit global-scale studies of the interaction of active surface circulation with slow-moving deep waters—the key to understanding long-term climate variability.

Investigation of the Southern Ocean will be of particular interest. The Antarctic Circumpolar Current plays a fundamental role in the heat balance of the West Antarctic Ice Shelf; if this enormous ice mass should melt and break away from the underlying bedrock as a result of global warming, sea level would rise by 4 to 5 m (about 15 feet). TOPEX/POSEIDON will greatly advance our understanding of this remote region and improve our ability to predict the fate of the ice shelf.

Tropical-ocean studies will focus on the causes of Pacific sea-level variations and the disastrous El Niño climate events. Other investigations will refine our knowledge of the Earth's gravity field and its effect on ocean topography, permitting more accurate models of both gravity and ocean circulation to be developed.

Many mission scientists are also active participants in the Tropical Ocean and Global Atmosphere program and the World Ocean Circulation Experiment. By merging the satellite observations with TOGA and WOCE findings, they will establish the extensive data base needed for the quantitative description and computer modeling of ocean circulation. The ocean models will eventually be coupled with atmospheric models to lay the foundation for predictions of global climate change.

SEAGOING EXPEDITIONS conducted by many nations will complement the TOPEX/POSEIDON space observations. Here, U.S. scientists measure the temperature and salinity of Antarctic currents.

COMPUTER TECHNOLOGY has revolutionized oceanographic data analysis and interpretation. Here, French scientists analyze results from computer models of global ocean circulation.

TOPEX/POSEIDON Science Team Leaders

Name	Institution	Investigation
F. Barlier	Groupe de Recherches de Géodésie Spatiale, France	The Western Mediterranean Sea
G. Born	University of Colorado, USA	Ocean Gyres
C. Boucher	Institut Géographique National, France	Terrestrial Reference Systems
D. Burrage	Australian Institute of Marine Sciences, Australia	The North-Australian Tropical Seas
A. Cazenave	Groupe de Recherches de Géodésie Spatiale, France	Marine Geophysics
D. Chelton	Oregon State University, USA	The Antarctic Circumpolar Current
J. Church	Commonwealth Scientific and Industrial Research Organization, Australia	The South Pacific, the Southern, and the Indian Oceans
P. De Mey	Groupe de Recherches de Géodésie Spatiale, France	Data Assimilation by Ocean Models
Y. Desaubies	Institut Francais de Recherche pour l'Exploitation de la Mer, France	The Western Equatorial Atlantic Ocean
B. Douglas	NOAA/National Ocean Service, USA	Ocean Dynamics and Geophysics
L.- L. Fu	Jet Propulsion Laboratory, USA	Gyres of the World Oceans
M. Grundlingh	National Research Institute for Oceanography, South Africa	The Oceans around South Africa
S. Imawaki	Kagoshima University, Japan	The Western North Pacific Ocean
E. Katz	Columbia University, USA	The Tropical Atlantic Ocean
C. Koblinsky	NASA/Goddard Space Flight Center, USA	Ocean Circulation and the Geoid
C. Le Provost	Institut de Mécanique de Grenoble, France	Global Ocean Tides
T. Liu	Jet Propulsion Laboratory, USA	Heat Balance of Global Oceans
R. Lukas	University of Hawaii, USA	Tropical Ocean Dynamics
Y. Menard	Groupe de Recherches de Géodésie Spatiale, France	Geophysical Validation of Altimetry
J. Merle	Université Paris VI, France	The Tropical Atlantic Ocean
J. Minster	Groupe de Recherches de Géodésie Spatiale, France	Mesoscale and Basin-scale Ocean Variability
J. Mitchell	Naval Oceanographic and Atmospheric Research Laboratory, USA	The Mid-Latitude Western Boundary Currents
D. Olbers	Alfred Wegener Institute for Polar and Marine Research, Germany	Ocean Circulation Modeling
M. Ollitrault	Institut Francais de Recherche pour l'Exploitation de la Mer, France	The South Atlantic Ocean
L. Pettersson	University of Bergen, Norway	The Nordic Seas
J. Picaut	Groupe SURTROPAC, ORSTOM, France	The Tropical Pacific Ocean
R. Rapp	Ohio State University, USA	Mean Sea Surface and Gravity
B. Sanchez	NASA/Goddard Space Flight Center, USA	Global Ocean Tides
J. Segawa	University of Tokyo, Japan	Marine Geodesy and Geophysics
A. Souriau	Groupe de Recherches de Géodésie Spatiale, France	Plate Motions
T. Strub	Oregon State University, USA	Equatorial and Eastern Boundary Currents
C.- K. Tai	NOAA/National Ocean Service, USA	The Pacific Ocean
B. Tapley	University of Texas at Austin, USA	Ocean Surface Topography
P. Tarits	Institut de Physique du Globe de Paris, France	Altimetry Analysis with Sea Floor Electric Data
J. Wahr	University of Colorado, USA	Oceanic Effects on the Earth's Interior
K. Wakker	Delft University of Technology, Netherlands	Orbit Computation and Sea-surface Modeling
P. Woodworth	Proudman Oceanographic Laboratory, United Kingdom	Marine Research
C. Wunsch	Massachusetts Institute of Technology, USA	Global Ocean Circulation

THE FUTURE OF THE OCEAN PLANET

When the United States/France TOPEX/POSEIDON mission is complete, oceanographers will have carried out the most accurate mapping of ocean topography ever attempted. For the first time, scientists will have the detailed description of ocean circulation necessary for an understanding of the role of the ocean in climate change. In combination with the findings of seagoing measurement programs and other complementary space missions, the TOPEX/POSEIDON results will be used to refine models of global ocean circulation and to improve our understanding of the ocean's influence on climate. Armed with this new knowledge, oceanographers will collaborate with other Earth scientists to develop forecasts of global change, enabling governments around the world to assess the future of the Ocean Planet.

Quand la mission franco-américaine TOPEX/POSEIDON sera terminée, les océanographes auront tracé une carte de la topographie océanique avec une précision inégalée. Pour la première fois, les scientifiques disposeront de mesures et de modèles globaux de la circulation océanique. Ces données seront combinées aux mesures à la mer et aux résultats d'autres programmes spatiaux pour mieux comprendre l'influence de l'océan sur le climat.

L'expérience acquise avec TOPEX/POSEIDON permettra la mise en place d'un système d'observation permanent de l'océan. Forts de cette connaissance nouvelle, les océanographes pourront coopérer avec les autres spécialistes des Sciences de la Terre aux prévisions de changement global, permettant ainsi aux gouvernements du monde de préparer le futur de la "planète bleue".

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Text: BDM International, Inc. and Jet Propulsion Laboratory

Man is challenged by the voice within him, the voice out of the whirlwind of consciousness, to seek and to know all he can. Knowledge of the air and the sea and the solid Earth, and of our fellow creatures who share this planet, increases our ability to use the Earth wisely and well.

Roger Revelle, 1909–1991

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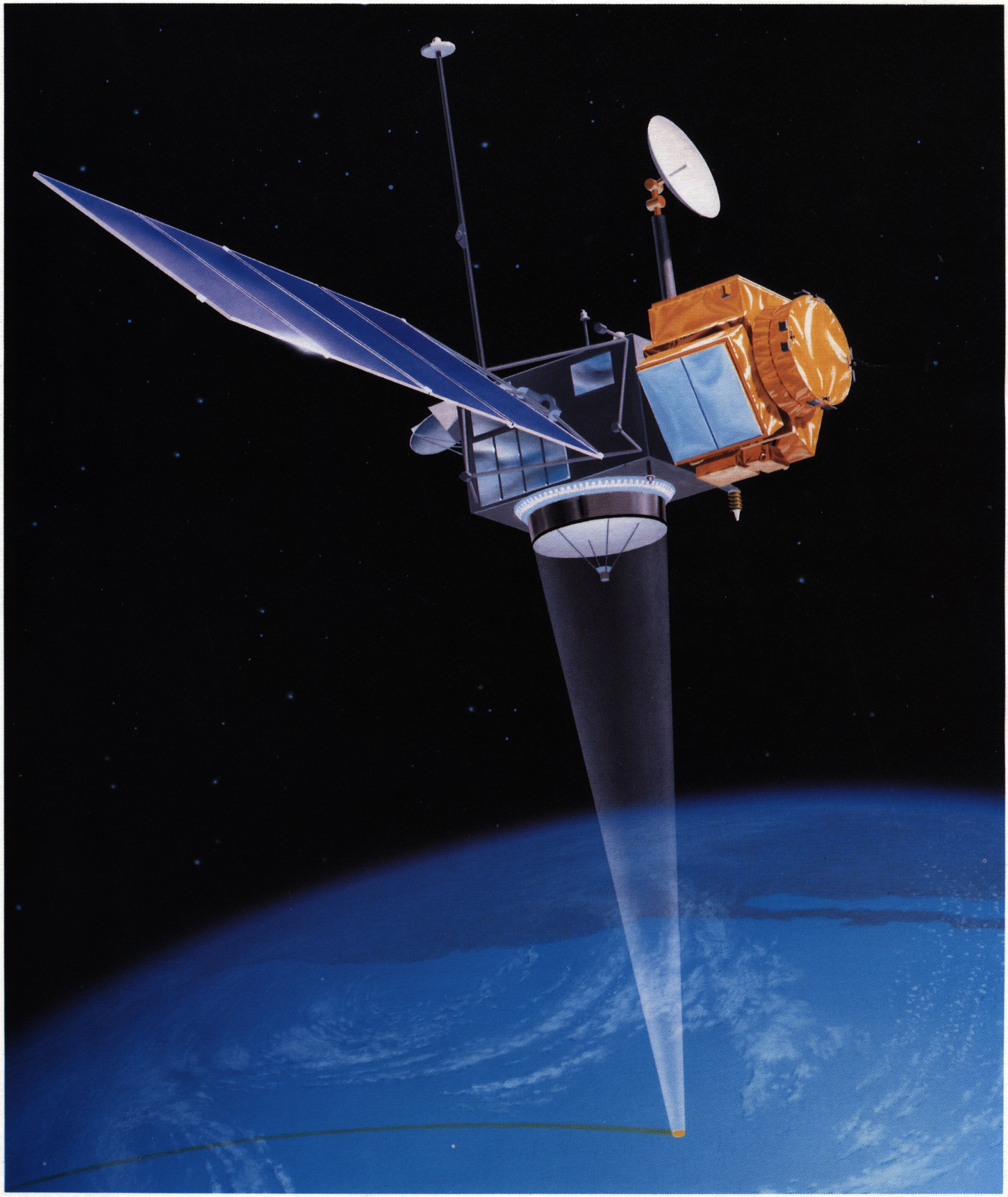
NASA National Aeronautics and Space Administration

TOPEX/Poseidon



TOPEX/Poseidon

The Ocean Topography Experiment (TOPEX)/ Poseidon is a cooperative project between the United States and France to develop and operate an advanced satellite system dedicated to observing the Earth's oceans. The mission will provide global sea level measurements with an unprecedented accuracy. The data from TOPEX/Poseidon will be used to determine global ocean circulation and to understand how the oceans interact with the atmosphere. This understanding will improve our ability to predict global climate.

For this joint mission, the National Aeronautics and Space Administration (NASA) is providing the satellite bus and five instruments with their associated ground elements. NASA's Jet Propulsion Laboratory is responsible for project management, and will operate and control the satellite through NASA's Tracking and Data Relay Satellite System. The Centre National d'Etudes Spatiales (CNES) is furnishing two instruments with their associated ground elements and a dedicated launch on an Ariane rocket. Both CNES and NASA will provide precision orbit determination and will process and distribute data to 38 science investigators from nine nations, as well as other interested scientists.

In the summer of 1992, TOPEX/Poseidon will be launched into orbit by an Ariane rocket from the European Space Agency's Space Center located in Kourou, French Guiana. From its orbit 830 miles (1,336 kilometers) above the Earth's surface, TOPEX/Poseidon will make sea level measurements along the same path every 10 days using the dual frequency altimeter developed by NASA and the CNES single frequency solid-state altimeter. This information will be used to relate changes in ocean currents with atmospheric and climate patterns. Measurements from NASA's Microwave Radiometer will provide estimates of the total water-vapor content in the atmosphere, which will be used to correct errors in the altimeter measurements. These combined measurements will allow scientists to chart the height of the seas across ocean basins with an accuracy of 5 inches (13 centimeters).

Three independent techniques will determine the satellite altitude within 4 inches (10 centimeters). NASA's Laser Retroreflector Array will be used with a network of 10 to 15 satellite laser ranging stations to provide the baseline tracking data for precision orbit determination and calibration of the radar altimeter bias. The DORIS system, recently demonstrated by the French SPOT-2 mission, will provide an altemate set of tracking data using microwave Doppler techniques. The system is composed of an onboard receiver and a network of 40 to 50 ground transmitting stations, providing all-weather, global tracking of the satellite. NASA's Global Positioning System Demonstration Receiver will demonstrate a new technique for precise, continuous tracking of the spacecraft.

TOPEX/Poseidon is a vital part of a strategic research effort to explore ocean circulation and its interaction with the atmosphere. It is timed to coincide with and complement a number of international oceanographic and meteorological programs, including the World Circulation Experiment (WOCE) and the Tropical Ocean and Global Atmosphere (TOGA) Program, both of which are sponsored by the World Climate Research Program (WCRP). TOPEX/Poseidon is a three-year mission with the potential for a two-year extension. Results from TOPEX/Poseidon will build the foundation for a continuing program of long-term observations of ocean circulation from space, and for an extensive ocean monitoring program in the next century.

RADAR ALTIMETER
POSEIDON
a space observatory for studying the oceans

ALCATEL
ESPACE

The altimetry today

The altimeter of any aircraft allows calculation of height above ground. But when the altimeter is in a satellite and the "ground" considered is the moving surface of the ocean 1300 km below, the results obtained are at the scale of a planet, of its deep currents and of its major climatic and ecological cycles.

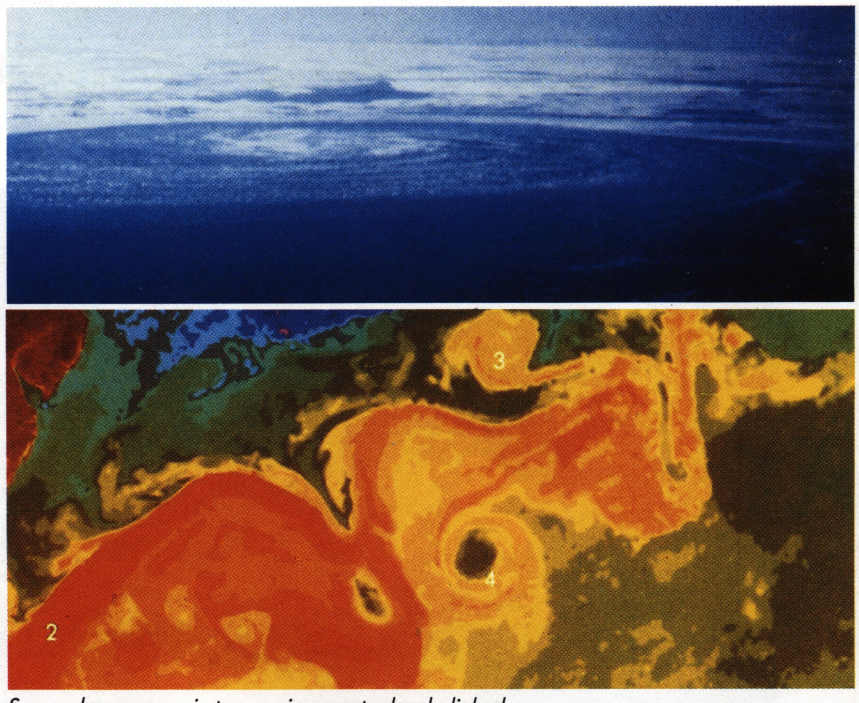
What is space altimetry?

Altimetric measurement by radar determines the distance of the satellite from the surface of sea. From this is determined, among other parameters, the *slope* of this surface, which is directly related to the speed of ocean currents. Information on wave height and windspeed is also obtained.

Who is interested in altimetry?

Spot measurements made in the past by ships no longer suffice by themselves to encompass the whole of "ocean system" complexity. The study of the sea's surface produces a wealth of information.

- Firstly there are the *waves* raised by the wind and which are of prime interest to *seafaring men.*
- Then there is the *marine geoid,* which is the level taken up by the ocean when at rest under the influence of the Earth's gravitational field and ocean floor relief. This information constitutes essential material for *geophysicists.*
- Finally, and above all, there is that which permanently disturbs this state of rest: *ocean movement* - deep currents, whirlpools, tides which passionately interest *oceanographers.* For these currents, even when they correspond only to a few centimetres of height difference, can have major repercussions, sometimes at the other end of the Earth and after a period of a few days or a few months, or even a few years! Climatic effects (draughts, floods, etc.), biological effects (ocean life), ecological effects, (such as the absorption of carbon dioxide waste, etc.). So many variations which justify the observation of ocean movement at a planetary level in order, at long term, to understand our planet better. And there is every reason to believe that in the future, altimetry will extend to the study of the ice caps and the continents and, why not, other planets.



Same phenomenon in two environments closely linked.
Above: an atmospherical eddy. *Below: an oceanic eddy (Gulf stream).*

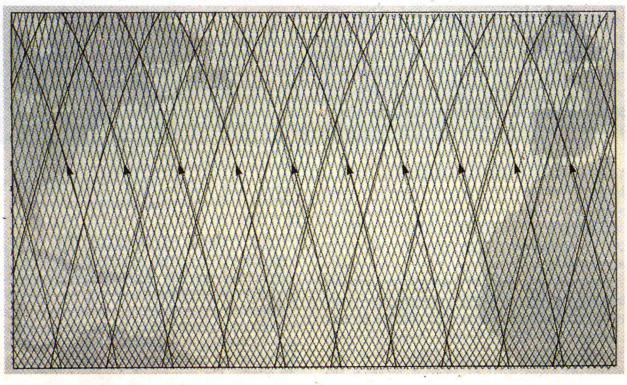
What is expected of a "modern" altimeter?

If the principle of altimetry is simple, its practice remains complex. Very high measurement accuracy is required (of the order of one centimetre!) and the satisfactory interpretation of data implies certain constraints:

– Space: the radar must cover a grid with the smallest possible mesh and as fast as possible to prevent point phenomena from escaping through these meshes. This space coverage depends on *orbit repetitivity.*

– Time: observations must be made over several years, this requiring *long life of the satellite.*

A new type of altimeter, developed by French technology, will render these constraints no longer necessary.



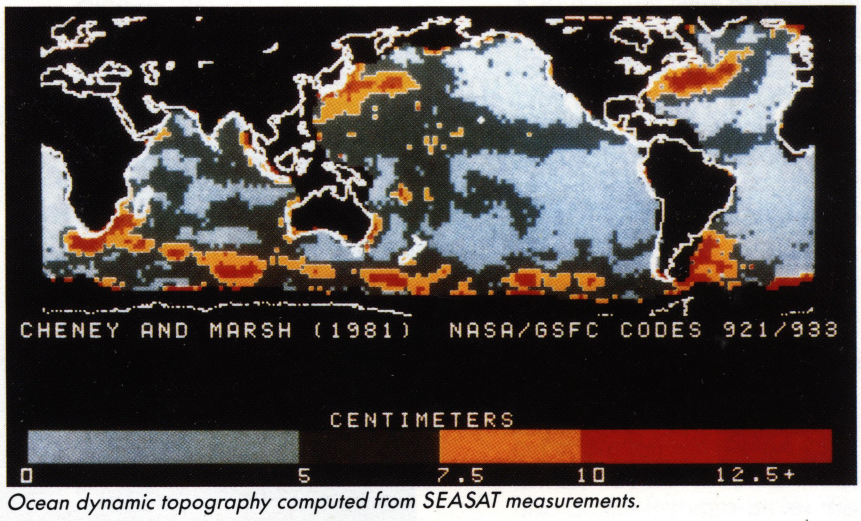
Superposition of SEASAT and SPOT orbit traces showing the difficulty for a good space/time cover.

Principle of altimetry

The radar altimeter transmits pulses and records the returns of these pulses reflected from the surface of the ocean vertically beneath the satellite. The radar beam covers the ocean with a "footprint" of some ten kilometres. The characteristics of the reflected echo enable the following three characteristics of ocean surface to be determined :

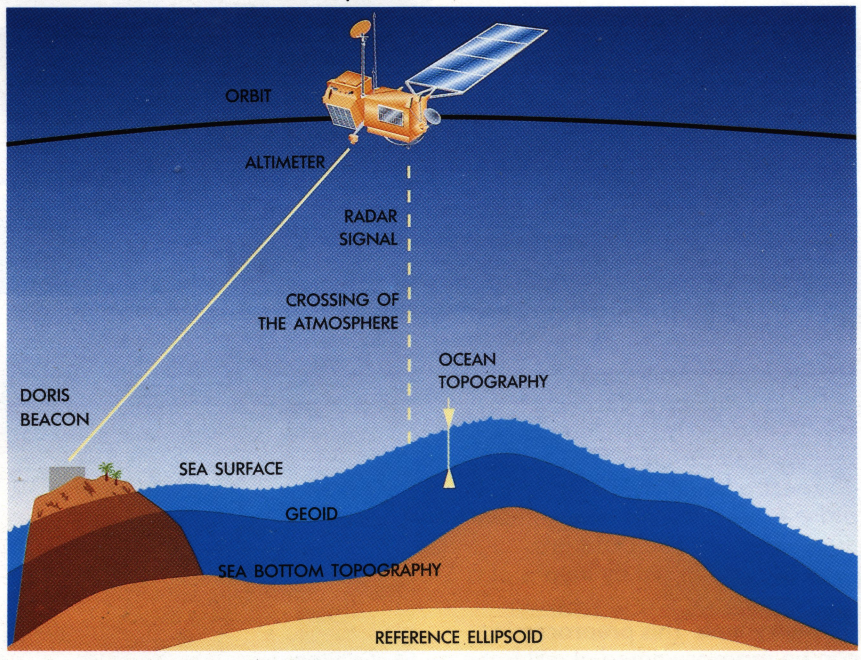
1. The distance of the satellite from the surface of the sea.

This is the main parameter, measured by the pulse return time. It allows observations of the dynamic topography due to *ocean currents*. Provided that elsewhere knowledge is obtained of the levels of the seas in the absence of current (geoids) and also of the exact orbit of the satellite (calculated by DORIS during the TOPEX-POSEIDON mission).
The passage of the radar signal through the atmosphere and ionosphere causes disturbance, which is corrected by a microwave radiometer carried in the satellite and by descriptive models of the ionosphere respectively.
Ripples on the surface of the sea produce interference in the echo : this random noise is attenuated by considering the average of several returns rather than a single return.
Other factors may affect the measurement : inclination of the antenna with respect to the surface of the sea (whence the necessity of knowing the exact orientation of the satellite at each instant) and fluctuation in satellite distance (corrected by locking the reference pulse to a return echo).



Ocean dynamic topography computed from SEASAT measurements.

Altimetric measurement principle :

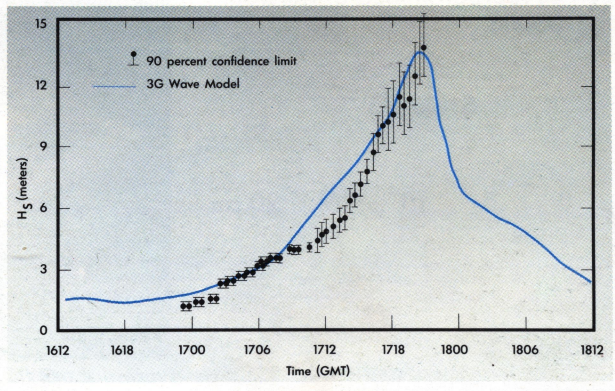


2. Amplitude of the ripples on the surface of the sea

Provoked by surface wind, they scatter the signal and weaken the echo. The level of the radar return picked up by the satellite thus enables *windspeed* to be calculated.

3. Shape of the radar return.

The scattering of the signal by waves and swell distort the return pulse. From this is deduced *wave height.*



Excellent correlation between calculated and observed wave heights during hurricane Camille in 1969.

The TOPEX-POSEIDON mission

1978 : after three months of observation, the SEASAT satellite is providing the initial data for the overall dynamic topography of oceans by altimetry. It is displaying not only known currents (such as the Gulf Stream or Kuroshio Stream), which are compared with oceanographical data gathered by ships, but also currents less easily accessible such as the Periantarctica. It is showing the tides which occur out at sea as well as marine whirlpools carrying enormous quantities of energy.

1992 : planned launch of TOPEX-POSEIDON, a satellite equipped with instruments provided by NASA and CNES.

The major objectives.

– To establish a *long-term* observation programme of ocean currents and their variations.

– To add the information gathered to that of other missions for establishing *models* in order to go beyond the observational stage and make *forecasts* (meteorological, climatic, etc.) with their direct consequences on the life and environment of everyone.

Organization and operation

The joint mission is organized as follows :
NASA is responsible for the design and manufacture of the platform as well as the integration of the scientific equipment. Some of this equipment is supplied by NASA, including the main instrument, the bifrequency altimeter, the microwave radiometer, the laser reflectors and a GPS receiver (of an experimental nature). CNES is supplying a precise DORIS orbitographical system and the solid-state altimeter (also of an experimental nature). Sharing the same antenna, the two altimeters occupy measurement periods alternately.
The satellite will be injected by an ARIANE 42P launch vehicle supplied by CNES into a 1334 km orbit in order to avoid atmospheric friction.
The planned duration of the mission is 3 to 5 years. Data, after validation and processing, will be exchanged and discussed with and distributed to users.

Reference Mission.

A historic example of collaboration between France and the United States, the TOPEX-POSEIDON mission will immediately place the France at the forefront of worldwide space technology.

The new-generation altimeter

Produced by ALCATEL ESPACE for the CNES (Centre National d'Etudes Spatiales - French National Space Research Centre), the POSEIDON radar altimeter combines accuracy, light weight and operational flexibility. It has been designed, not for a special-purpose satellite, but for carriage as a "passenger" on any platform. With total adaptability to today's requirements and tomorrow's dreams.

High-Tec design.

Of small volume and weight, consuming little (whether power or teletransmitted throughput), the POSEIDON altimeter, because of the progress in microelectronics, can be adapted in its present form for installation in numerous satellites. Whence reduced cost of each altimetry mission and possible multiplication of measurements to overcome space-time constraints (spatial coverage with several satellites over the years).

Numerous applications.

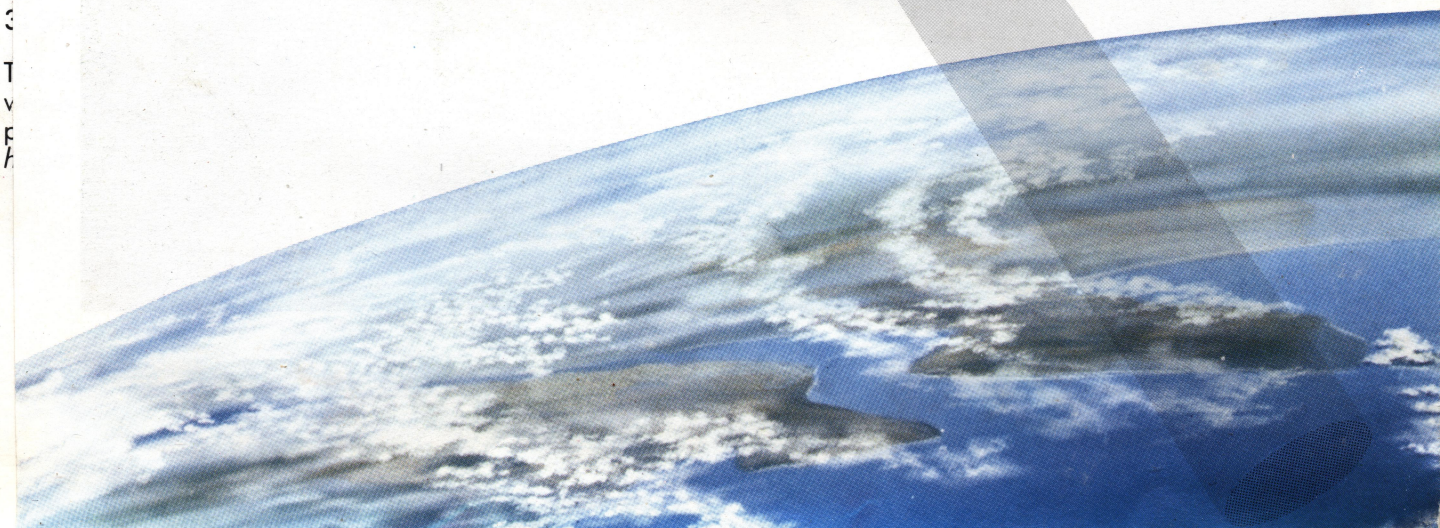
- Initially, participation in the major programmes for accumulating *Knowledge of the Earth from ocean currents* (WOCE, TOGA) : ocean-to-atmosphere interaction (exchange of heat, coupling between wind and ocean, the "El Niño" phenomenon), variability in time, geoid and tide models.
- At medium term : *climatology, meteorology,* operational missions for the *study of currents* (fishing, navigation) or the *propagation of sound waves* (SONAR).
- In the future : adaptation to "multi-terrain" missions (ice, land) or planetary missions (Mars, Venus, Titan, etc.)

Indispensable validation : 1992, TOPEX-POSEIDON.

First "optimized mission for the measurement of overall ocean currents by altimetry" in collaboration with NASA and CNES, TOPEX-POSEIDON will also be the first mission for the POSEIDON altimeter and will allow ideal validation of the instrument (accuracy, operation, signal processing).

Main characteristics of the POSEIDON altimeter :

Accuracy : contribution to the overall altimetric measurement error :	2 cm
Transmission frequency :	13.65 GHz
– 3 dB beamwidth :	1.23°
Pulse Repetition Frequency (PRF) :	1700 Hz
Weight :	12 + 13 = 25 kg
Power consumption :	64 W
Dimensions :	
Microwave unit :	36.5×28.8×23.2 cm
Processing unit :	35.5×25.5×20.3 cm



The POSEIDON altimeter

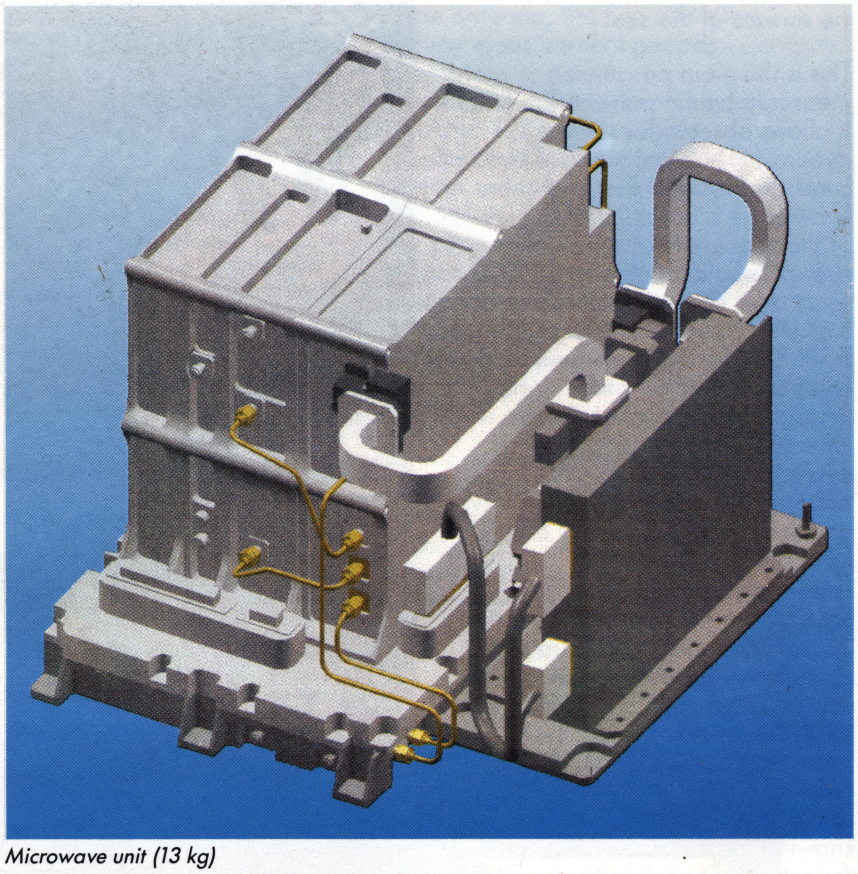
Two units, hardly larger than a desk-top computer monitor, and an antenna - these are the components of this "portable altimeter": only three subassemblies for the complete instrument instead of ten or so for some of its competitors.

Microwave unit.

This unit generates the pulses (when ordered by a sequencer located in the processing unit). The return pulses picked up by the antenna are amplified, calibrated and mixed with the reference pulses for feeding to the processing unit.

Scale 1/5

0 5 10 15 20 cm



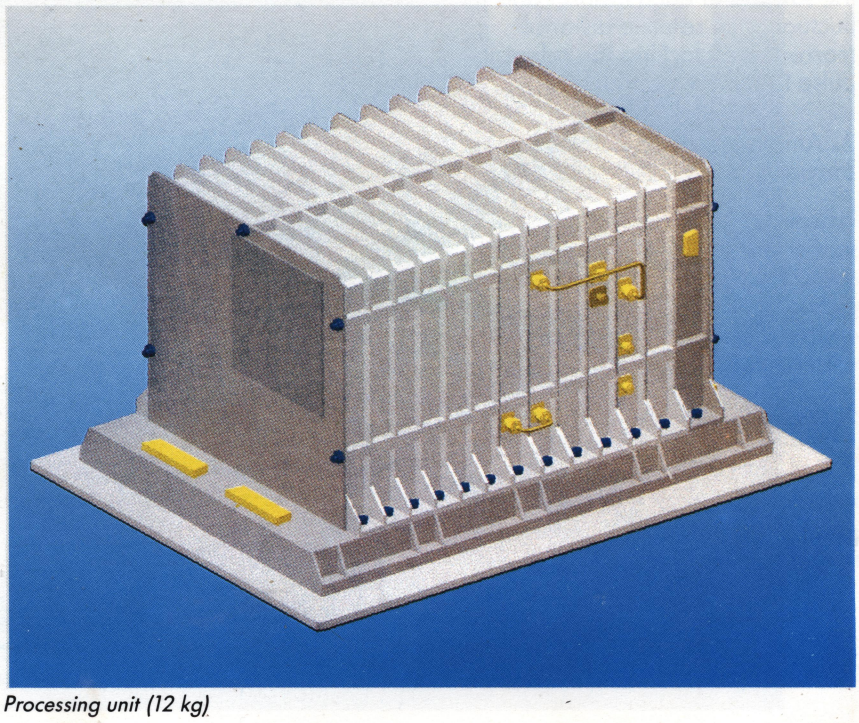
Microwave unit (13 kg)

Processing unit.

This unit analyzes the pulses in order to produce a frequency spectrum directly correlated with the required *distance* (in practice, 85 spectra being averaged in order to eliminate the interference mentioned above). Data are *preprocessed in situ* by means of a microprocessor, thereby saving telemetry time. This preprocessing can be *reprogrammed* at will from the ground.

Scale 1/5

0 5 10 15 20 cm



Processing unit (12 kg)

R/CALIBRATION

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00 dB attenuator stable to
dB throughout the mission.

• POWER AMPLIFIER

This module simultaneously operates as an up-converter and power amplifier which is of solid-state technology :

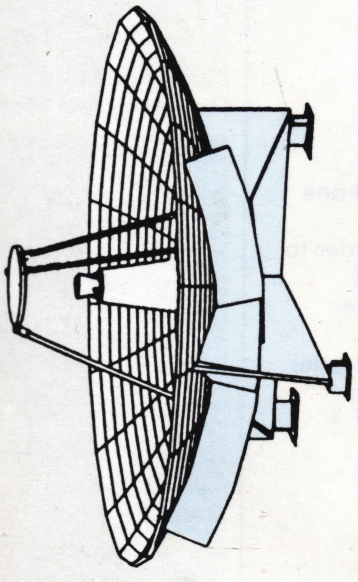
Characteristics :
- transmitter power : 5 W
- gain : 55 dB
- efficiency (amplifier only) : 20 %
- AM/PM conversion : maximum 2°/dB
- maximum PRF : 2000 Hz
- centre frequency : 13.65 GHz
- bandwidth : > 320 MHz

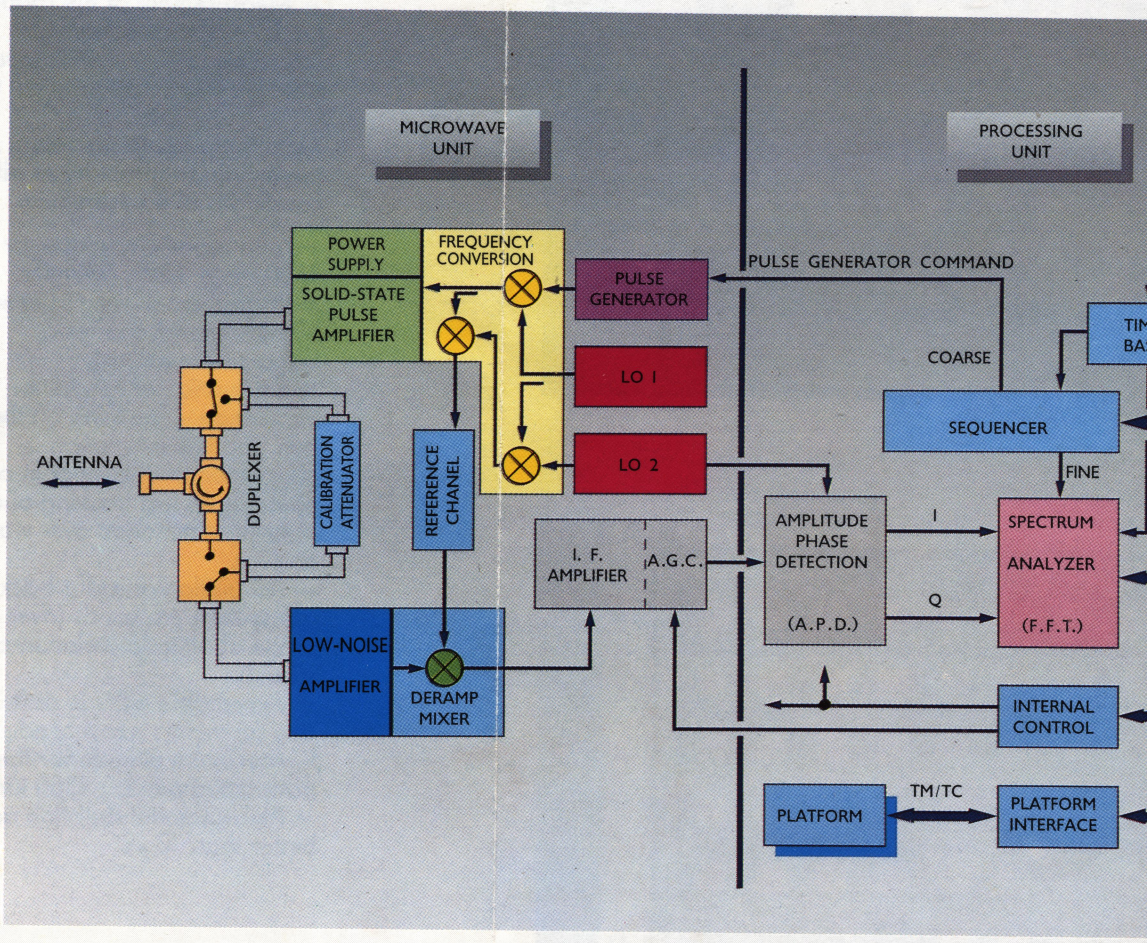
• PULSE GENERATOR

The pulses are generated by exciting two surface acoustic-wave dispersive lines in cascade. The characteristics of the linearly frequency-modulated signal obtained are :
- centre frequency : 900 MHz
- pulsewidth : 105 μs
- – 1 dB bandwidth : 320 MHz.
- signal-to-noise ratio : 25 dB

• AMPLITUDE : PHASE DETECTO

This detector generates the in-phas
the quadrature (Q) baseband char
These channels are limited by ident
filters to eliminate the phenomenor
spectrum folding in the FFT.
Type of filter : Cauer 7th order ellip
pass filter with a bandwidth of 320





CHANNEL

ency : 12.96 GHz
00 MHz

• LOW-NOISE AMPLIFIER AND DOWN-CONVERTER

The input stage is of HME technology.
The down-converter mixer de-ramps the signal.

Characteristics :
- noise figure : 3 dB
- gain : 25 dB
- bandwidth : 400 MHz
- frequency change : 13.65 GHz → 0.69 GHz.

• INTERMEDIATE-FREQUENCY AMPLIFIER

Characteristics :
- Maximum gain : 79 dB
- A.G.C. : 62 dB in 1 dB increments
- Bandwidth : 20 MHz

• LOCAL OSCILLATORS

LO 1 : dielectric resonator oscillator
frequency : 12.75 GHz
LO 2 : stabilized cavity oscillator
frequency : 690 MHz

The POSEIDON radar altimeter.

• DUPLEXER/CALIBRATION

This module feeds the signal to be transmitted from the power amplifier to the antenna and the radar return signal from the antenna to the low-noise amplifier.
In the calibration mode, the power amplifier is looped back to the receiver via a calibrated 100 dB attenuator stable to within ± 0.1 dB throughout the mission.

• POWER AMPLIFIER

This module simultaneously operates as an up-converter and power amplifier which is of solid-state technology :
Characteristics :
– transmitter power : 5 W
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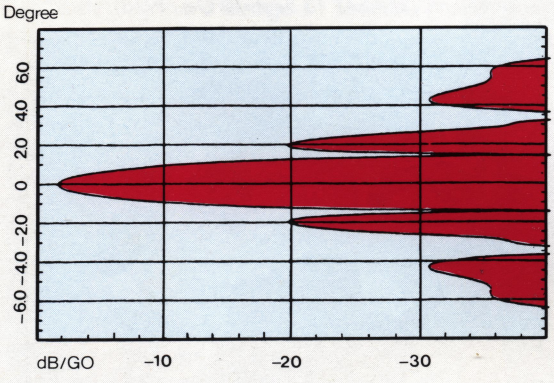

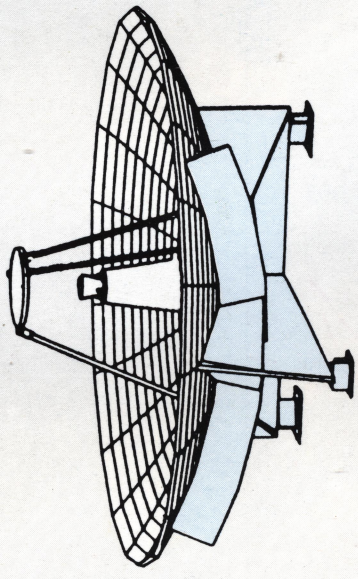

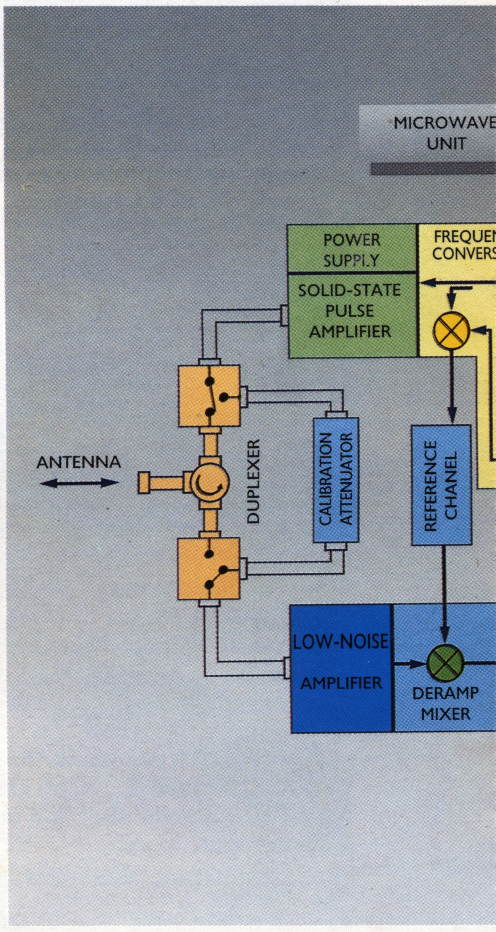

• ANTENNA

Not specific (for TOPEX-POSEIDON, the antenna is of American supply)
Typical SPOT mission antenna (opposite)
Diameter : 1.2 m
– 3 dB beamwidth : 1.23°
Gain on the axis : 44 dB

• REFERENCE CHANNEL

Characteristics :
– centre frequency : 12.96 GHz
– bandwith : 400 MHz
– gain : 55 dB

• LOW-NOISE AMPLIFIER AND DOWN-CONVERTER

The input stage is of HME technology.
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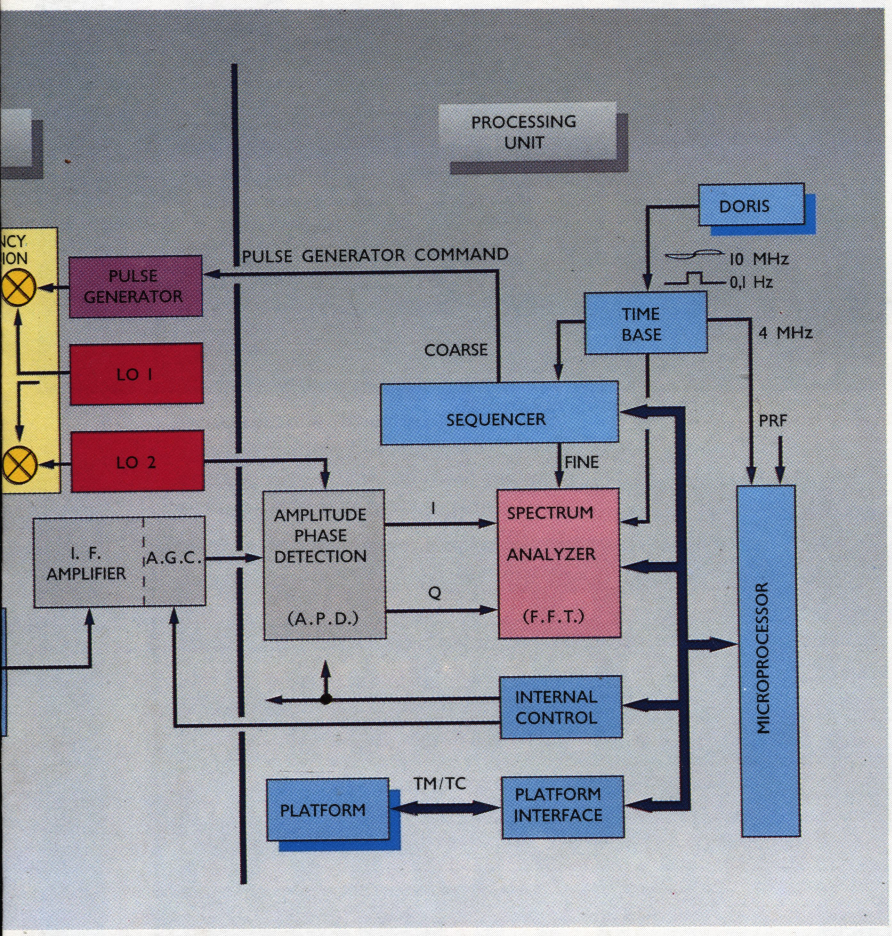
This detector generates the in-phase (I) and the quadrature (Q) baseband channels. These channels are limited by identical filters to eliminate the phenomenon of spectrum folding in the FFT.
Type of filter : Cauer 7th order elliptical low-pass filter with a bandwidth of 320 kHz

• TIME BASE AND SEQUENCER

This module generates all the synchronization signals. The most critical signal is that triggering the pulse generator : accuracy better than 50 ps over 8.9 ms.



• SPECTRUM ANALYZER (F.F.T.)

The input channels I and Q of this entirely digital analyzer are sampled at a frequency of 640 kHz by an analogue-to-digital converter. The analyzed spectrum is limited to 640 kHz with a resolution of 10 kHz. The spectrum is analyzed at 64 points by a special-purpose processor at the PRF. The output is a power spectrum to which is added random fluctuation (jitter). In order to reduce this jitter, averaging is performed by summing 85 spectra. The result is a spectrum averaged every 50 ms. For fine corrections, the analyzer can shift its analysis gate by increments of 625 Hz over a total range of 40 kHz.

IATE-FREQUENCY

s :
gain : 79 dB
dB in 1 dB increments
: 20 MHz

• LOCAL OSCILLATORS

LO 1 : dielectric resonator oscillator
frequency : 12.75 GHz
LO 2 : stabilized cavity oscillator
frequency : 690 MHz

• MICROPROCESSOR

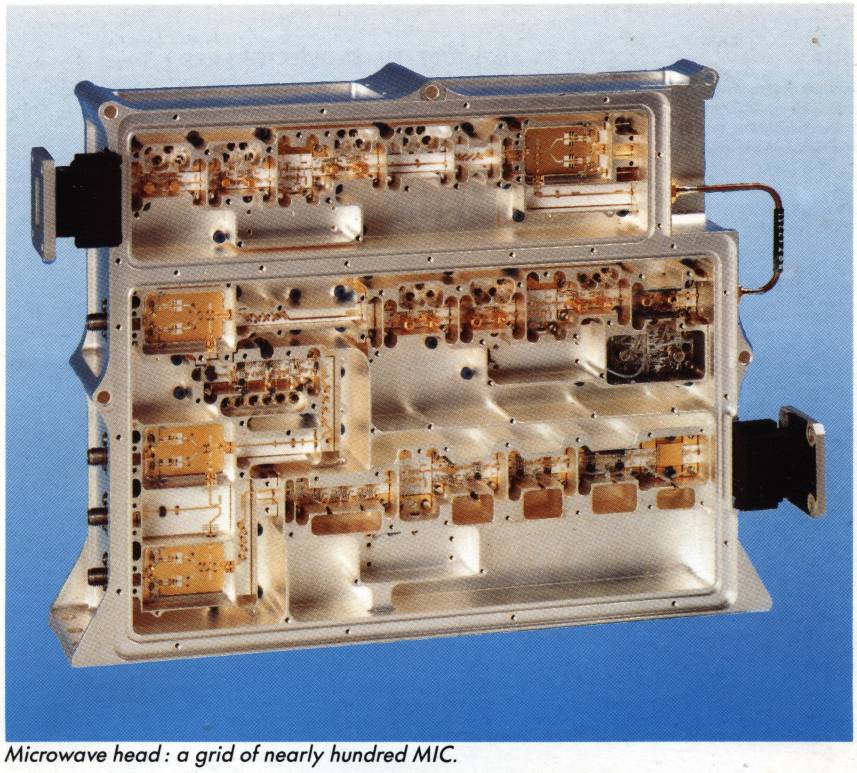
A type 80C86 microprocessor controls the instrument, processes the signal (except for the spectrum analysis) and evaluates the parameters.

The compact altimeter

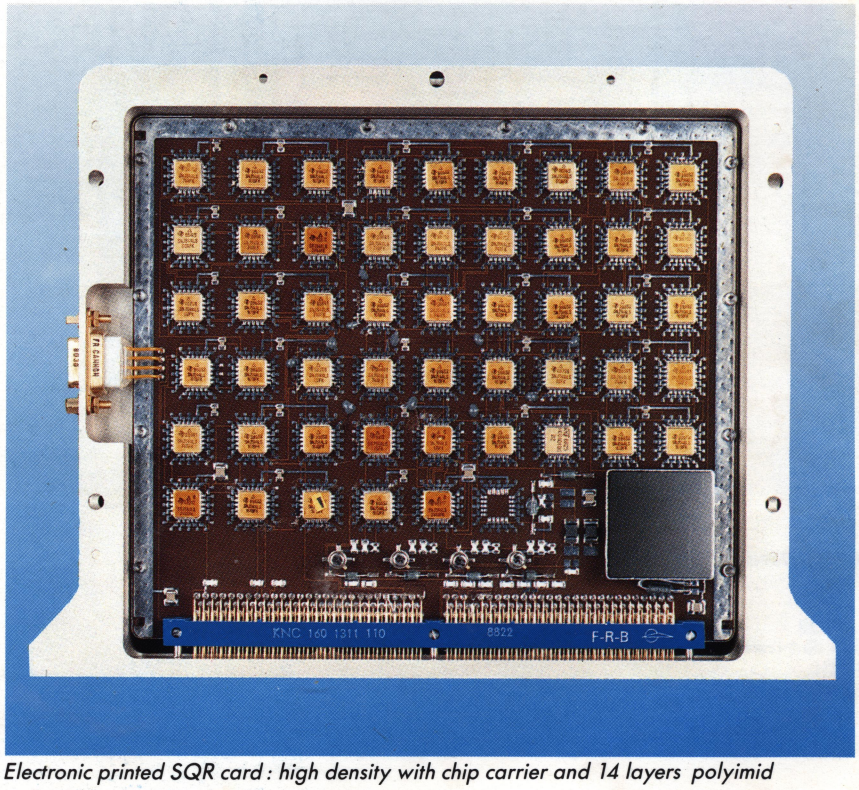
Power consumption matching their size.

The units consume very little power :
– Processing unit : 38 W
– Microwave unit : 26 W
For a mission of the TOPEX-POSEIDON type, the transmitter power consumption is 5 W, twenty times less than that of other altimeters. On the other hand, the pulse width is large (100 μs) : the pulse is ''stretched'' when transmitted and ''recompressed'' at its return to achieve measurement performance as great as that of more powerful instruments (high compression ratio : 32,000).

These performance characteristics are obtained by the choice of advance technologies, including in particular a novel pulse generator developed by ALCATEL ESPACE (by ''surface-wave dispersive lines'') and a solid-state power amplifier.



Microwave head : a grid of nearly hundred MIC.



Electronic printed SQR card : high density with chip carrier and 14 layers polyimid technology.

French technology serving international oceanographical research

The POSEIDON altimeter meets the scientific requirements of oceanographers, gives substance to their intuitions and in return stimulates their imagination.

All the accuracy required for calculating parameters

– Accuracy : contribution of only 2 cm to the overall altimetric measurement error.
– Footprint (at 1,300 km) : 2 to 10 km, depending on the sea state.
– Measurement of the *significant height of waves* (H 1/3) from 0 to 20 m : accuracy of 2 % for wave heights exceeding 2 m.
– Measurement of the *radar backscatter coefficient* σ_0 (corresponding to *windspeed*) : from 3 dB to 40 dB to within 0.5 dB.

From the pulse to the return : maximum adaptability to all conditions of measurement

– Pulse repetition frequency : 1700 Hz $\pm$ 10 %. Scientific measurement averaged over 50 milliseconds (85 radar backscatter spectra).
– *Separation of functions* : acquisition + tracking on the one side and fine estimation + calculation on the other in order to obtain both fast tracking and accurate estimation over water and ice.
– Acquisition of radar backscatter in less than 2 seconds (over a range of altitude variation of $\pm$ 15 km).
– Acceptable altitude drift : 0 to 50 meters per second.
– Maximum altitude for the transmitted power : 1500 km.
– Measurement datation accuracy better than 10 μs.

Kinetic energy of the antarctic current.

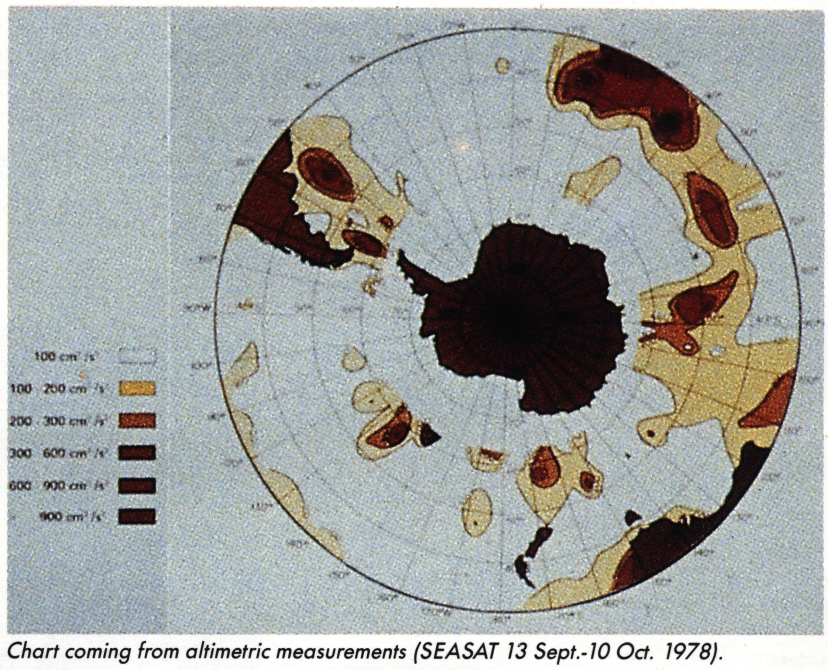


Chart coming from altimetric measurements (SEASAT 13 Sept.-10 Oct. 1978).

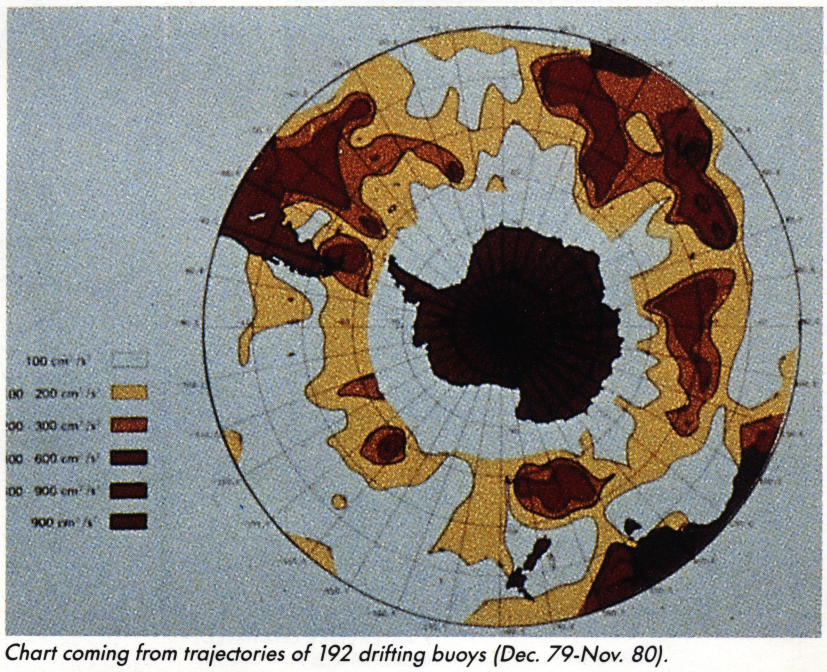


Chart coming from trajectories of 192 drifting buoys (Dec. 79-Nov. 80).

The excellent correlation validates the altimetric method.

The future passenger for an "on-demand" altimetry

As already described, the POSEIDON altimeter is a very undemanding passenger, compatible with numerous platforms. What in fact are its needs?

Small Size.
– Microwave unit:
Weight: 13 kg; dimensions:
36.5 cm × 28.8 cm × 23.2 cm.
– Processing unit:
Weight: 12 kg; dimensions:
35.5 cm × 25.5 cm × 20.3 cm.
– Inter-unit cable harness:
Weight: 0.7 kg.
– Antenna:
Weight: 7 kg; diameter: 1.2 m;
height: 0.6 m.

Very flexible thermal conditions.
The instrument operates without difficulty at any temperature between −5 °C and + 35 °C. Thermal control may be radiative or conductive.

"Economic" electrical requirements.
– Unregulated DC supply bus:
22 to 37 V.
– Total power consumption (for both units):
26 W + 38 W = 64 W.
– Telemetry and telemonitoring data rate requirements (asynchronous serial-data operation): 1.3 kbits in the normal mode, 12 kbits in the load/dump mode.
– External frequency references required: 10 MHz and 0.1 Hz.
All the electrical inputs and outputs (interfaces) are redundant.

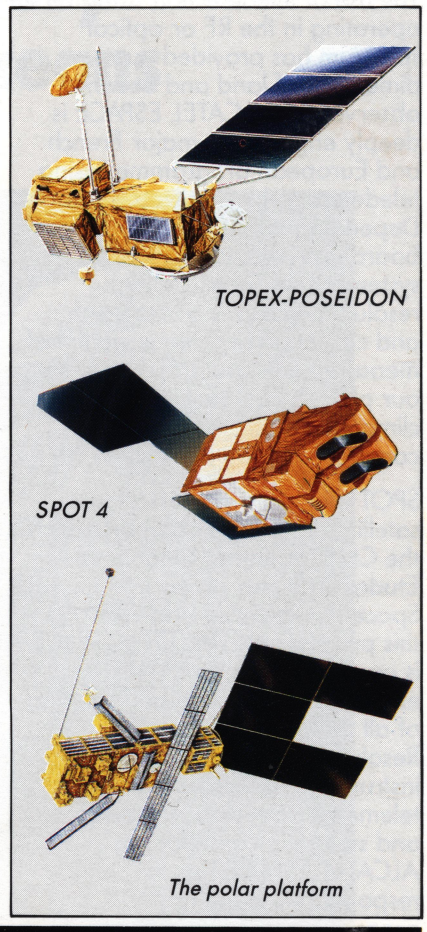
"On-demand" altimetry.

Although optimized for an ocean topography mission, the POSEIDON altimeter has been developed with the goal of producing an instrument easily adaptable to other missions.

By design, the POSEIDON altimeter can be carried directly by any satellite if the orbit is limited to 1500 km and attitude control (antenna orientation) is compatible with the mission envisaged. The POSEIDON altimeter can thus be included in programmes such as SPOT, ERS-2 or the future polar platform of the ESA.

Adaptation to a "multi-terrain" mission as opposed to its oceanic mission, is fully possible by merely modifying the embedded software. In addition, it is possible to model its peformance characteristics for other missions *without modifying the architecture of the altimeter.* For example, the following changes can be typically developed in *12 to 18 months*:
– increase of transmitted power to 15 W,
– adaptation of the spectrum analyzer characteristics,
– inclusion of other processing algorithms.

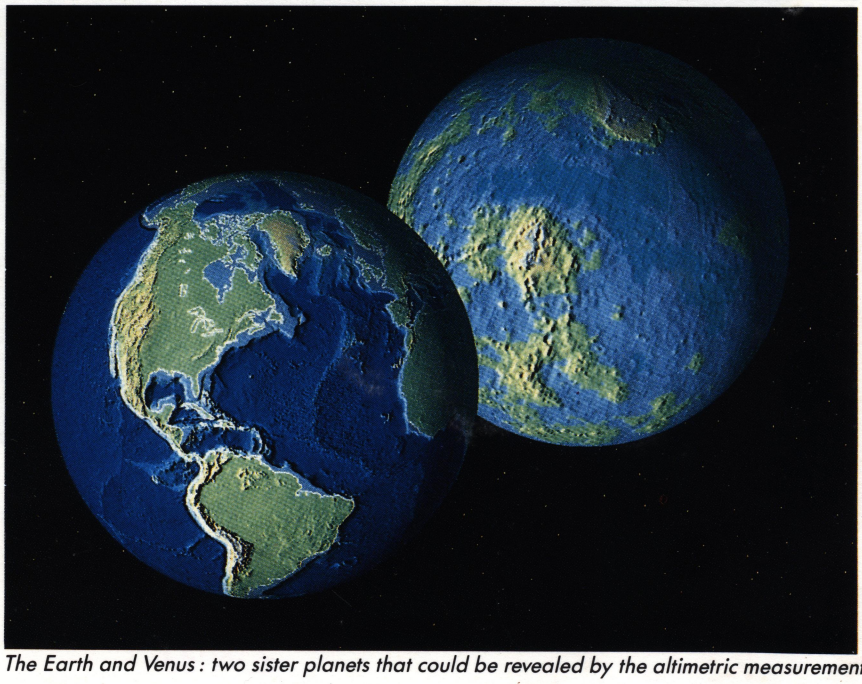
Finally, in order to produce the POSEIDON altimeter, ALCATEL ESPACE has developed considerable radar altimeter *simulation and test* facilities. These facilities enable the characteristics of an instrument derived from the POSEIDON altimeter for missions away from the Earth, such as Mars, Venus or Titan missions, to be defined very quickly.



TOPEX-POSEIDON

SPOT 4

The polar platform



The Earth and Venus: two sister planets that could be revealed by the altimetric measurement.

ALCATEL ESPACE and teledetection satellites

The use of teledetection satellites operating in the RF or optical spectrum has provided a new dimension of land and ocean observation. ALCATEL ESPACE is deeply engaged in major French and European programmes using teledetection by satellites. Depending on the type of on-board instruments, the satellites systematically, produce high-resolution imagery of the earth and collect an enormous wealth of measurements useful for studying our planet : oceanography, climatology, meteorology, cartography, geodisy, etc.

SPOT is an Earth-observation satellite designed and operated by the CNES (Centre National des Etudes Spatiales - French National Space Research Centre). Within this programme, ALCATEL ESPACE is responsible for the HRV electronics (extraction and shaping of all useful signals from the High-Resolution in the Visible spectrum instrument) as well as payload telemetry, surveillance telemetry and system telemonitoring. ALCATEL ESPACE has the same responsibility in the HELIOS programme, the HELIOS satellite being a military observation satellite derived from the SPOT satellite.

ERS-1, to be launched in mid-1990, is a teledetection satellite of the European Space Agency. For this novel programme, ALCATEL ESPACE is providing the RF and calibration subsystems for the SAR as well as the S-band transponders.

Moorea island (French Polynesia) seen by SPOT 1.

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TOPEX-POSEIDON is a CNES-NASA mission for space oceanography which consists in measuring from a satellite the topography of ocean surfaces on a world-wide scale for determining ocean currents and their influence on the weather. The launch is planned for mid-1992 by means of an Ariane 4 launcher. For this mission, ALCATEL ESPACE is developing, producing and testing the POSEIDON radar altimeter. This new-generation instrument is the first totally French radar altimeter carried in a satellite.

ALCATEL
ESPACE

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ATES/034/06.89/7000 F.A./Due to technical improvements or administrative modifications, ALCATEL ESPACE reserves the right to vary the above characteristics and features, without notice. KR PLUS. Photos ALCATEL ESPACE - CNES - MATRA - NASA - SPOT IMAGE - FOTOGRAM STONE.

FAIRCHILD

TOPEX/POSEIDON SPACECRAFT FEATURES FAIRCHILD'S MODULAR DESIGN

Fairchild Space, a division of Fairchild Space & Defense Corporation of Germantown, Maryland, USA, is an experienced, innovative contractor with a 30-year history in the design, development, test and integration of satellites and high technology space subsystems. Since the 1960s, Fairchild has been a prime contractor, or had a significant support role, on 24 major space programs.

As mission contractor on the TOPEX/POSEIDON satellite, Fairchild was given responsibility for the design, construction and testing of the spacecraft, as well as for the physical interface with the Ariane launch vehicle. Fairchild provided mission operations planning support to NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, USA, and will support JPL in on-orbit checkout and operation of the spacecraft.

The TOPEX/POSEIDON design includes Fairchild's highly reliable Multimission Modular Spacecraft (MMS) bus, which has performed successfully on several other spacecraft, and reflects the company's unique expertise with modular design. The MMS is fully compatible with NASA's Space Transportation System (space shuttle) and expendable launch vehicles.

The MMS bus on the TOPEX/POSEIDON spacecraft was enhanced by Fairchild with a substantially improved attitude control module. Fairchild engineers also designed a new instrument module to accommodate the scientific requirements of the instruments, and managed the integration of the instruments with the spacecraft.

The completion of the TOPEX/POSEIDON spacecraft represents another successful demonstration of Fairchild Space's capabilities as a mission contractor. Long known as a manufacturer of highly reliable space systems and subsystems, Fairchild Space

Fairchild Space & Defense Corporation · 20301 Century Boulevard · Germantown, Maryland 20874 · (301) 428-6000

also has developed enhanced facilities and expertise to build entire spacecraft in the 1990s and beyond.

The company's satellite production facilities include a clean room with zero-gravity deployment capability, and an Electromagnetic Compatibility and Electromagnetic Interference Facility, a state-of-the-art chamber to test for electromagnetic interference and environmental test facilities. As part of the TOPEX/POSEIDON program, Fairchild Space also has upgraded its computer systems to allow almost total use of computer-aided design.

Inclusion of the enhanced Fairchild MMS bus on TOPEX/POSEIDON follows the use of this modular design on the Landsats 4 and 5, the Solar Maximum Mission (SMM) spacecraft, the Upper Atmospheric Research Satellite and the Extreme Ultraviolet Explorer (EUVE).

This modular architecture fosters more efficient integration and testing procedures. It allows individual subsystems to be tested and qualified separately by contractors before integration, and permits separate development and qualification of the instrument payload.

The modular design of Fairchild's bus permitted the successful on-orbit repair of the SMM spacecraft by NASA astronauts in 1984. The EUVE, launched in June 1992, also offers the unique capability to permit on-orbit servicing or payload exchange, if desired, although neither activity is currently in EUVE mission planning.

The company now is working to apply its unique modular expertise to a new generation of long-life, low-cost spacecraft that could serve a variety of missions.

Fairchild now is under contract to provide on-orbit servicing on NASA's Hubble Space Telescope. Fairchild engineers designed structures, tools, and techniques to allow contingency repair of the observatory by astronauts on initial deployment or during major hardware change-outs in the 15-year mission lifetime.

Recent Fairchild awards include a Phase I study contract from Stanford University for a Gravity-Probe B mission space vehicle design and a contract to the Strategic Defense Initiative Organization to serve as the mission contractor for the Shuttle

Pallet Satellite (SPAS) III program. Fairchild will refurbish and upgrade the Pallet, integrate the payload instrument, procure a second satellite to serve as a target plume generator, and design a sophisticated three vehicle mission (with the Shuttle).

Fairchild has participated in the small satellite arena since 1986, and worked with the Air Force on the Multiple Satellite System Program to design a small, inexpensive, tactical communications satellite system. Fairchild has incorporated its newest designs into these smallsats, including an advanced small power system and a new smallsat command and telemetry processor. In addition, Fairchild, under contract to NASA, developed a Small Explorer data and power system and is actively involved in other small satellite programs.

Fairchild also provides complete design development and production capabilities for satellite hardware and software, including digital and analog electronics. Every NASA MMS, to date, carries Fairchild Communications and Data Handling (C&DH) modules. In addition, Fairchild has extensive experience in analysis, design, test, and manufacture of satellite attitude control subsystems, as reflected in work performed on Extreme Ultraviolet Explorer and TOPEX/Poseidon.

Fairchild's Research and Development program supports pursuits of new opportunities and provides technology insertion enhancements. A particularly noteworthy example is the patented Solid State Recorder (SSR). This unit is the first space-qualified solid state recorder, and marks the first space demonstration of very high-speed integrated circuit (VHSIC) memory utilization and VHSIC packaging.

Fairchild is also involved in the design and fabrication of mechanical satellite systems such as thermal control louvers and deployment mechanisms. Over 200 Fairchild louver units have flown on 43 missions since 1965, including seven NAVSTAR satellites. The company's deployment mechanisms have flown on more than 25 missions since 1962.

Fairchild's Technical Support Centers, located in Greenbelt, Maryland and Huntsville, Alabama, USA, are staffed with experienced engineers and equipped with sophisticated computer-aided design and analysis tools. These centers provide a variety of satellite-related services such as engineering studies and analysis covering preliminary designs for satellites, instruments and payload systems. The

centers also provide mission planning, ground- and flight-operations support studies, quick-reaction engineering, and hardware fabrication and testing.

Fairchild Space and Defense Corporation employs 1,400 people, 60 percent of whom are scientists, engineers and other direct support personnel.

Fairchild Space & Defense Corporation, A U.S. space company, with operations in Germantown, Maryland and annual revenues of approximately $200 million, is a member of the Matra Group. Matra, headquartered in Paris, France, is an internationally diversified company with annual revenues in excess of $4 billion. Matra's lines of business include aerospace, telecommunications and transportation.

For further information contact: Richard W. Sherman
(301) 353-1789

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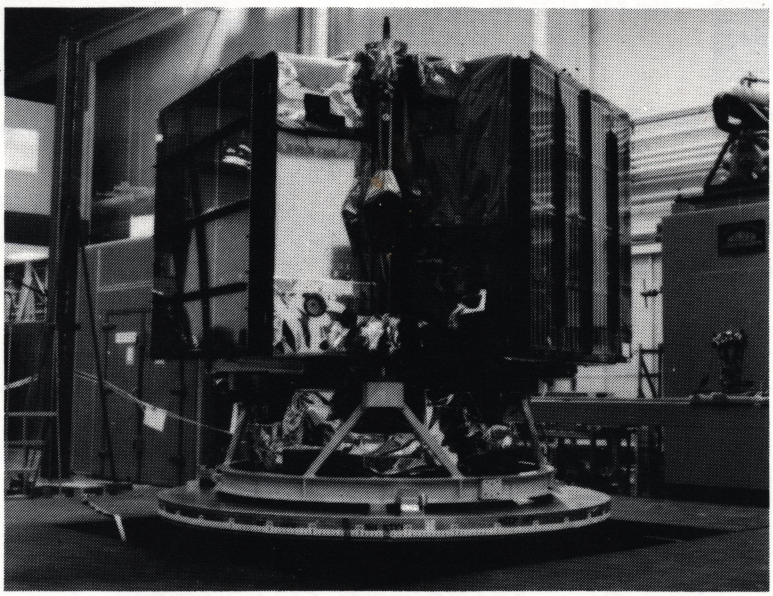
FAIRCHILD SPACE

Multimission Modular Spacecraft (MMS)



Description:

Under contract to the National Aeronautics and Space Administration (NASA), Fairchild developed the Multimission Modular Spacecraft (MMS) – the first space system designed for on orbit maintenance, servicing and repair. The MMS is fully compatible with NASA's Space Transportation System, as well as expendable launch vehicles. Selectable equipment options and a distributed data bus makes the MMS readily adaptable and allows significant flexibility in the program design, development, interaction and test phases.

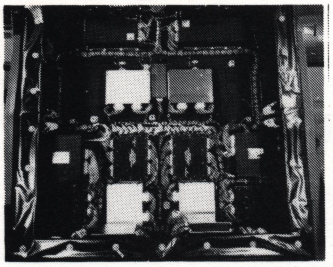
The MMS was specifically designed to support a wide spectra of low-Earth orbit scientific payloads and has flown successfully on the *Solar Maximum Mission*, and *Landsat* 4 & 5. It is currently in production on the *Upper Atmosphere Research Satellite*, the *Ocean Topography Experiment* and the *Explorer Platform* series. The MMS approach has enabled Fairchild to couple mission unique requirements with a spacecraft that provides the ultimate level of flight proven hardware.

The MMS has demonstrated the concept of packaging spacecraft support subsystem components into modular assemblies. Each major subsystem's components are packaged in separate but standard 4.0 feet square by 1.5 feet deep modules. Each module also contains standard mechanical mounting hardware and electrical connectors for blind attachment to a central support structure. This provides intrabus and payload interfacing, and ease of mate/demate operations. In addition, the central support structure has interface attachments for a propulsion module and a mission unique Signal Conditioning and Control Unit, as well as an interface adaptor for a variety of mission payloads.

The *Solar Maximum Mission*, *Landsat* 4 & 5, and *Upper Atmosphere Research Satellite* programs exemplify how a spacecraft bus and an instrument module have been successfully developed in parallel and integrated as completed units. If it is necessary during system integration and test to operate without one of the modules or an instrument, the existing ground support equipment is capable of simulating that element, allowing the program to proceed without a schedule interruption. Complete spacecraft simulators are also available to support development of mission unique software at the payload developer's facility.

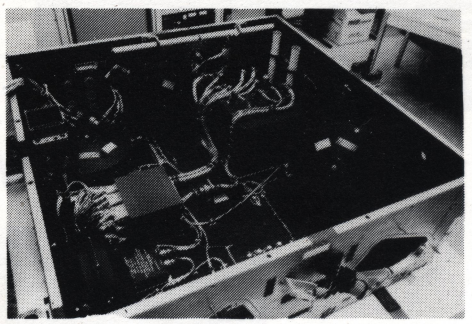
Fairchild has committed significant Internal Research and Development funds for advanced development of the attitude control, communications and data handling, and electrical power subsystems; as well as the development of sophisticated simulation programs that allow detailed performance and stability analyses of a particular subsystem or a complete satellite.

COMMUNICATIONS AND DATA HANDLING (C&DH)



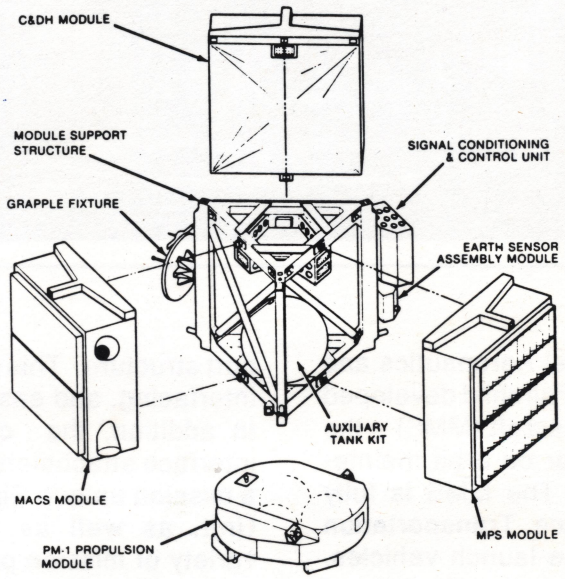
- TDRSS, GSTDN or SGLS compatible
- On-board computer with up to 500K ops/sec. and 64K of 18-bit words
- Commandable telemetry rate capability up to 64 kb/s
- Command rates up to 2 kb/s
- 2 MBPS payload data stream capability
- Data storage up to 3 times 4.5×10^8 bits standard
- Readily modified to user specific requirements

ATTITUDE CONTROL SYSTEM (ACS)

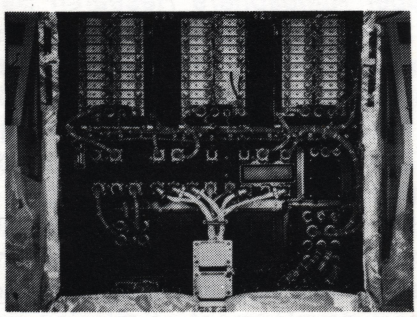


- 3 axis stabilized (wheels and magnetic torquers)
- Less than 2 arc-sec stability
- Less than .036 arc-sec with payload sensors
- Autonomous safe-hold mode

MMS Bus

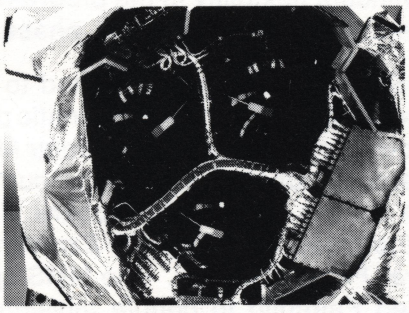


MODULAR POWER SYSTEM (MPS)



- Power bus of 28 ± 7 Vdc
- 1200 W continuous/3,000 W peak power
- 800 W available for the payload
- Accommodates up to 150 AH capacity using NASA standard NI-CAD batteries

PROPULSION SYSTEM



- Hydrazine monopropellant
- Accommodates up to 510 lbs. hydrazine
- 12 fully redundant 0.2 lbf attitude control thrusters
- 4 redundant 5.0 lbf orbit thrusters

FAIRCHILD SPACE

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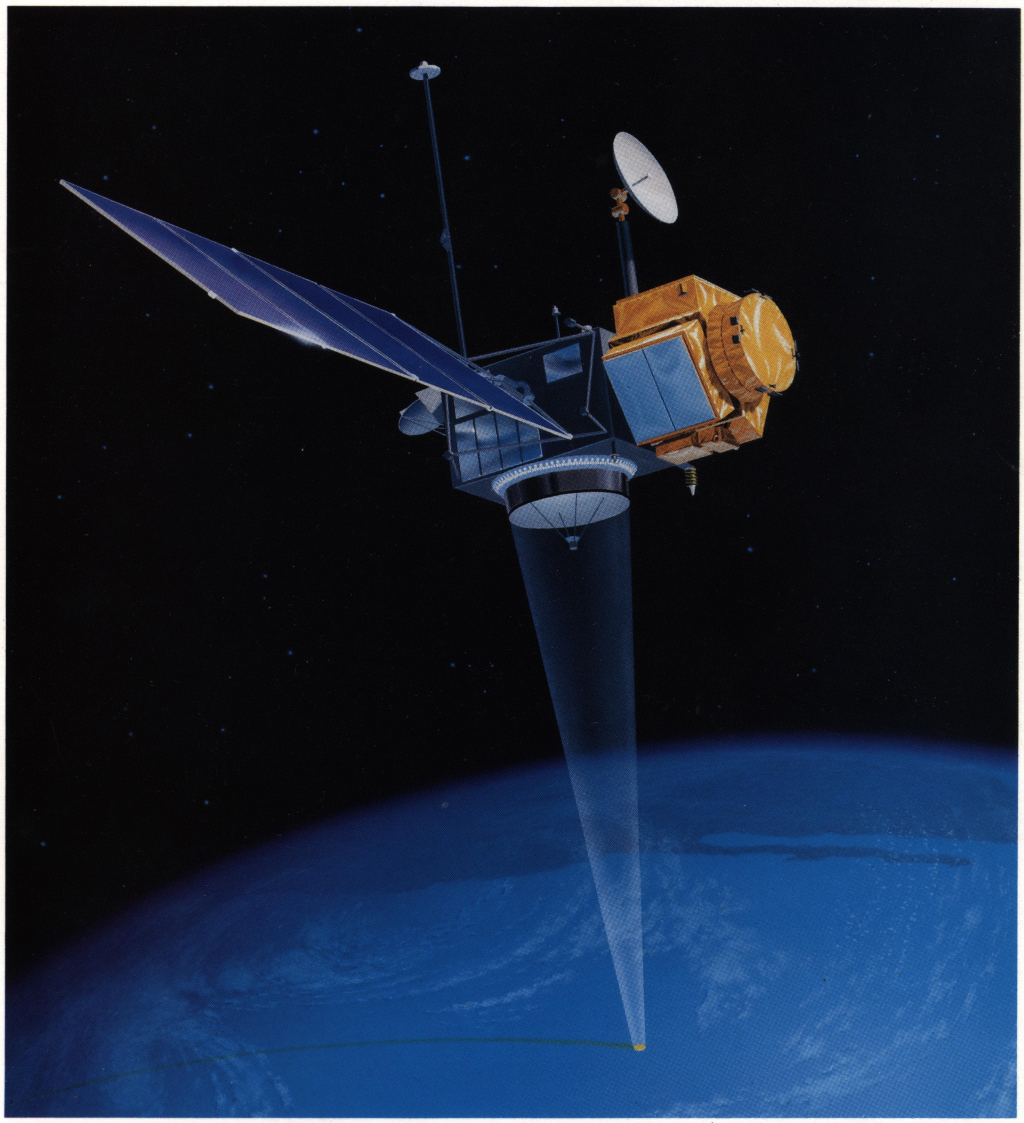
DM-6.186T 9/91M

TOPEX
POSEIDON

OCEAN TOPOGRAPHY EXPERIMENT



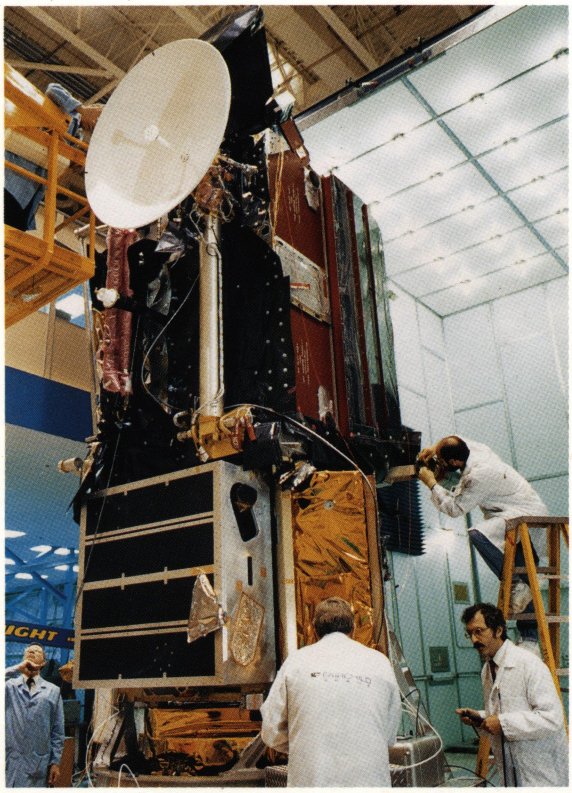
Artist rendering of TOPEX/Poseidon satellite

Mission

The launch of the TOPEX/Poseidon satellite, currently planned for midsummer 1992, will provide scientists with a detailed picture of the topography of the ocean's surface and an understanding of ocean currents worldwide. This information is critical for researchers to develop large-scale models for extended weather and climate prediction or forecasting, and to understand how the oceans and Earth's atmosphere interact. TOPEX/Poseidon is intended to operate on orbit for at least three years, with a goal of five years. The United States and France have each provided instruments for this mission, which is a joint undertaking. The United States also is providing the satellite and a major ground system, while the French are providing the launch vehicle.

FAIRCHILD SPACE

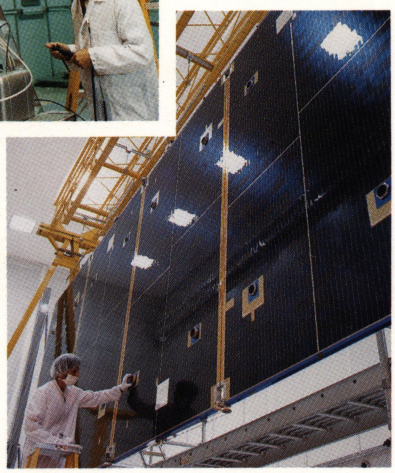
Fairchild's Role



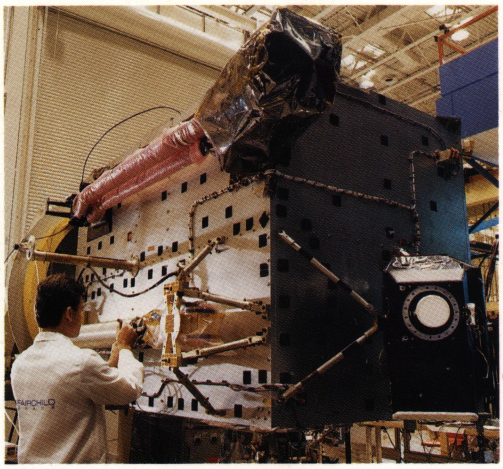
EMI Preparations

As mission contractor, Fairchild has the responsibility to design, build, test and launch the TOPEX/Poseidon satellite. Fairchild designed a new instrument module to accommodate the scientific requirements of the instruments, and managed the integration of the instruments with the spacecraft. Fairchild's Multimission Modular Spacecraft bus, which has been proven highly reliable on many previous missions, has been equipped with improved components to support the science payload.

Fairchild provided Mission Operations planning support to Jet Propulsion Laboratory, and will support JPL in actual checkout and operation of the spacecraft on orbit.



Solar Array Inspection



High Gain Antenna Fit Check

Satellite Characteristics

Launch Weight
2475 Kilograms

Dimensions

Length	5.5 meters	(18 feet 0 inches)
Span	11.5 meters	(37 feet 8 inches)
Height	6.6 meters	(21 feet 8 inches)

Power

Required	1018 watts
Capability	3385 watts at launch
	2260 watts after 5 years
Batteries	150 ampere-hour

Data Storage
Tape Recorders

Required	6.5×10^8 bits
Capability	15×10^8 bits

Pointing Accuracy
3 sigma – 0.11 degrees

Computer Memory
Capacity 65,536 (18-bit words)

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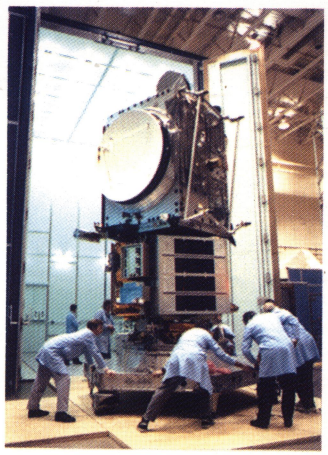
FAIRCHILD SPACE

TOPEX POSEIDON

CURRENT EVENT



Ocean currents hold secrets to the understanding of climate and weather changes and the complex interaction between the oceans and Earth's atmosphere. The Ocean Topography Experiment (TOPEX)/Poseidon spacecraft, now in the final stages of integration by Fairchild Space, will help uncover those secrets as it maps the ocean surface from space. On target for a July, 1992 launch, TOPEX/Poseidon will become the second major spacecraft in NASA's Mission to Planet Earth, following the 1991 launch of the Upper Atmosphere Research Satellite (UARS). In addition to the TOPEX/Poseidon spacecraft, Fairchild Space also provided its flight-proven Multimission Modular Spacecraft bus for UARS, including individual modules for Communications and Data Handling, Attitude Control, Power and Propulsion.

The building of the TOPEX/Poseidon spacecraft for NASA's Jet Propulsion Laboratory represents another successful demonstration of Fairchild Space's capabilities as a spacecraft contractor. Fairchild's technical expertise and the company's heritage of highly reliable systems and subsystems, have been proven again and again during virtually flawless missions. The people of Fairchild Space are proud to have applied this same expertise and heritage to the building and testing of TOPEX/Poseidon for its international mission.

With the launch of TOPEX/Poseidon about to become a current event, Fairchild Space is ready to meet the even greater spacecraft challenges of the future.

FAIRCHILD SPACE

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TOPEX / POSEIDON

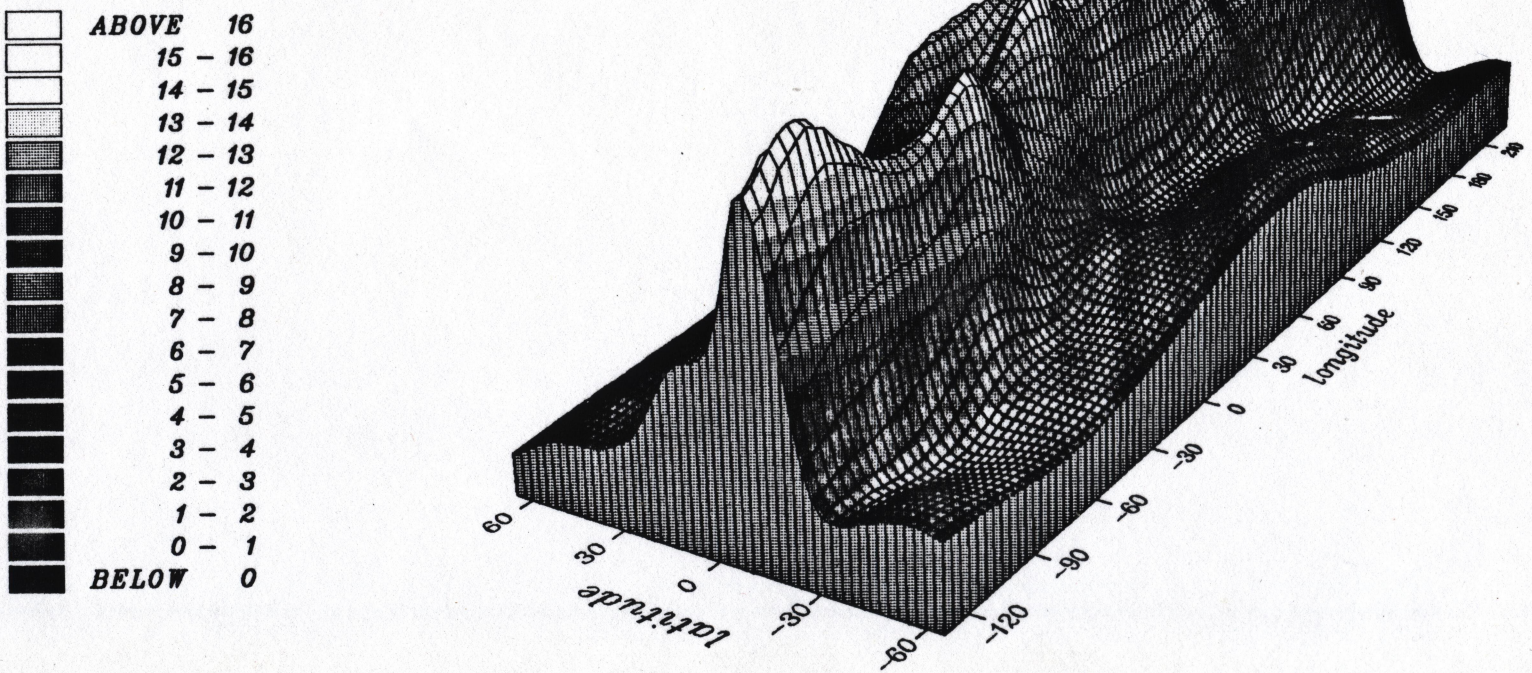
First Results

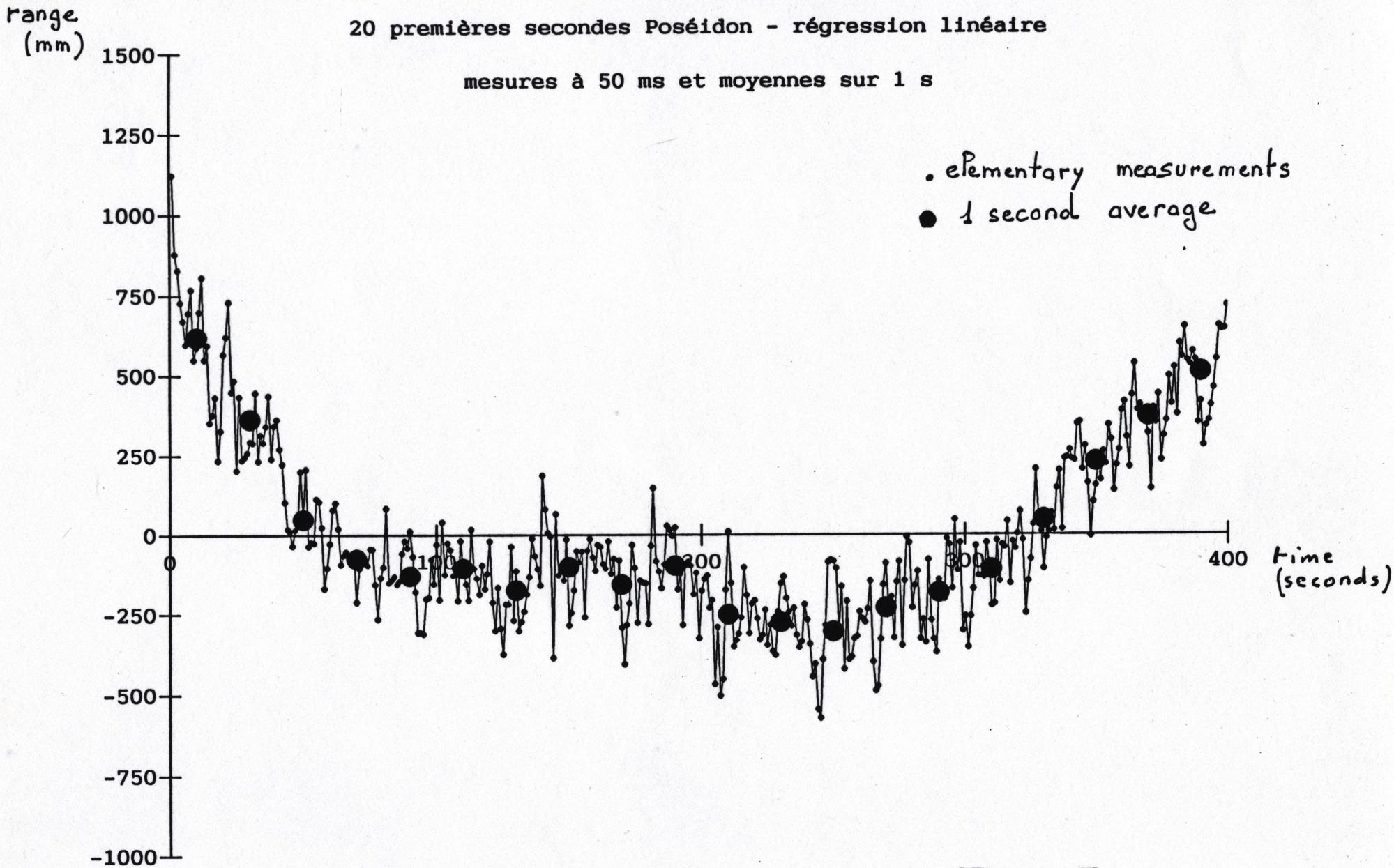
CNES SENSORS TURN-ON

DORIS turn-on : August 16
nominal functioning
measured measurement noise : 0.45 mm/sec

CNES altimeter turn-on : August 21
nominal functioning
measured measurement noise : 2cm (1sec average)

Altimeter Ionospheric Correction
Computed from DORIS measurements
August 21,1992 ascending arcs





CNES Altimeter first measurements

jour : 1992:08:21 trace deb : 25 trace fin : 32

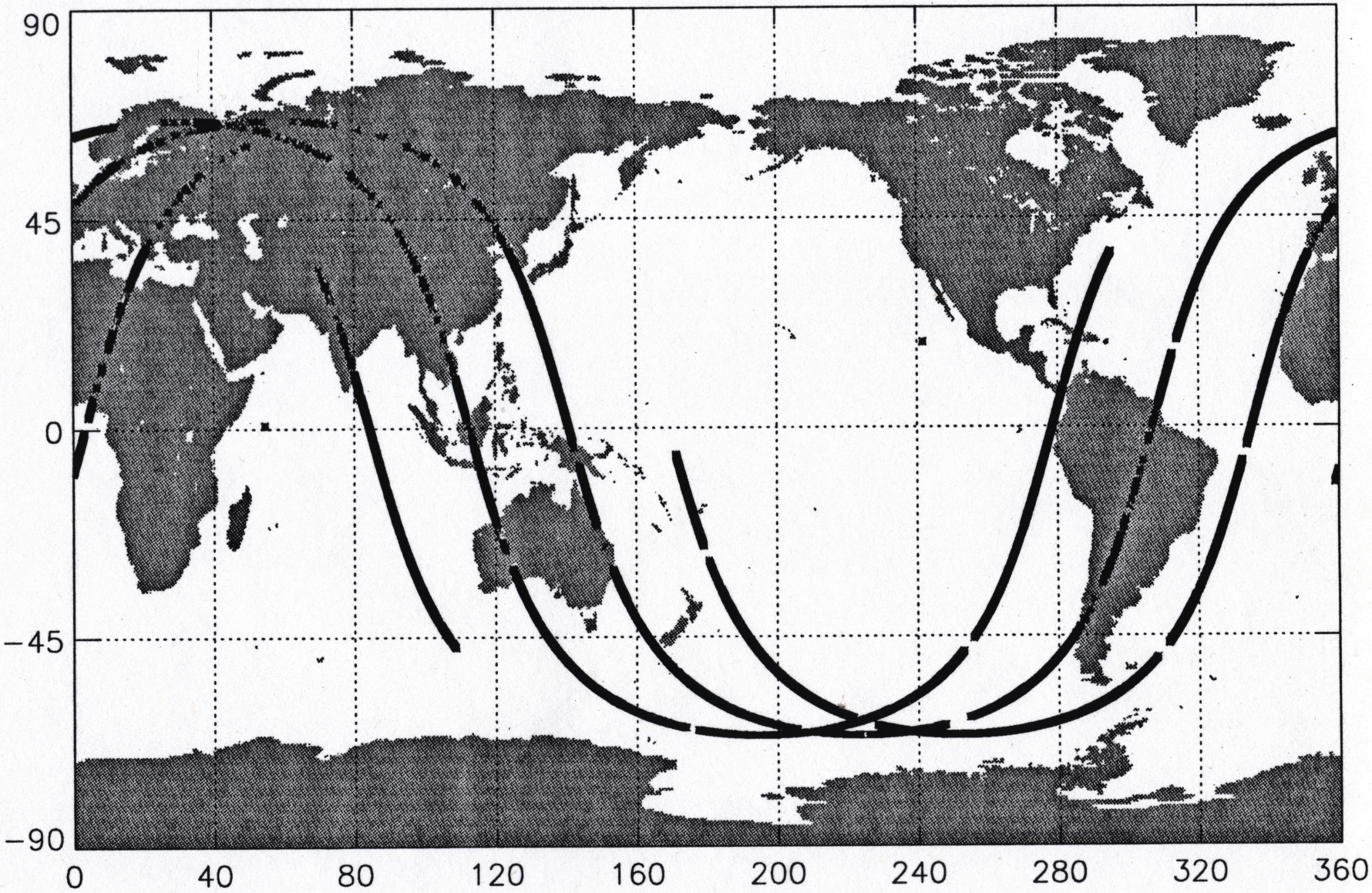
nom du fichier : POUR

1992:08:21T17:06:33.778639 1992:08:22T00:00:14.666304

HVA compris entre 0_2 m

HVA compris entre 2_4 m

HVA superieur a 4 m

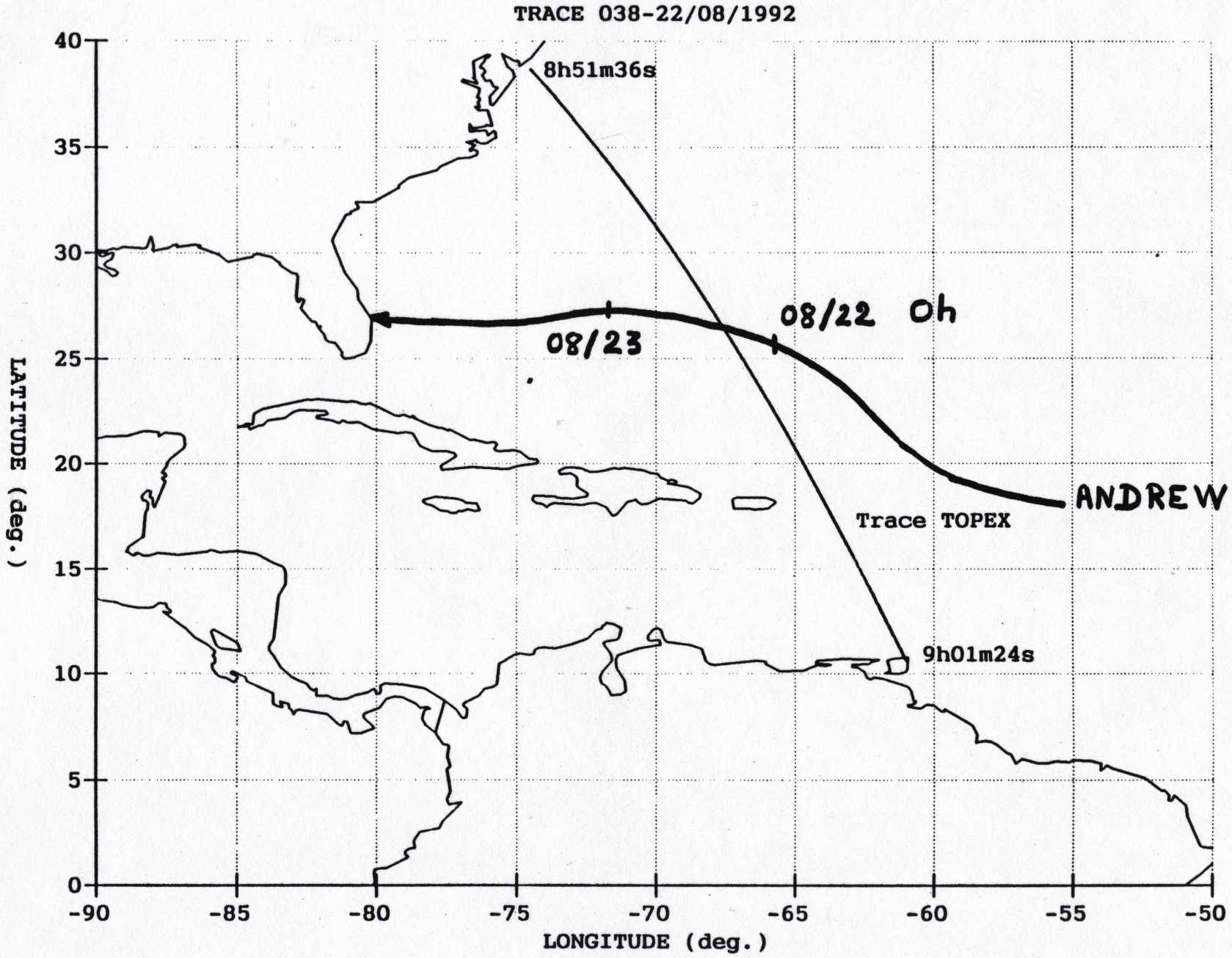


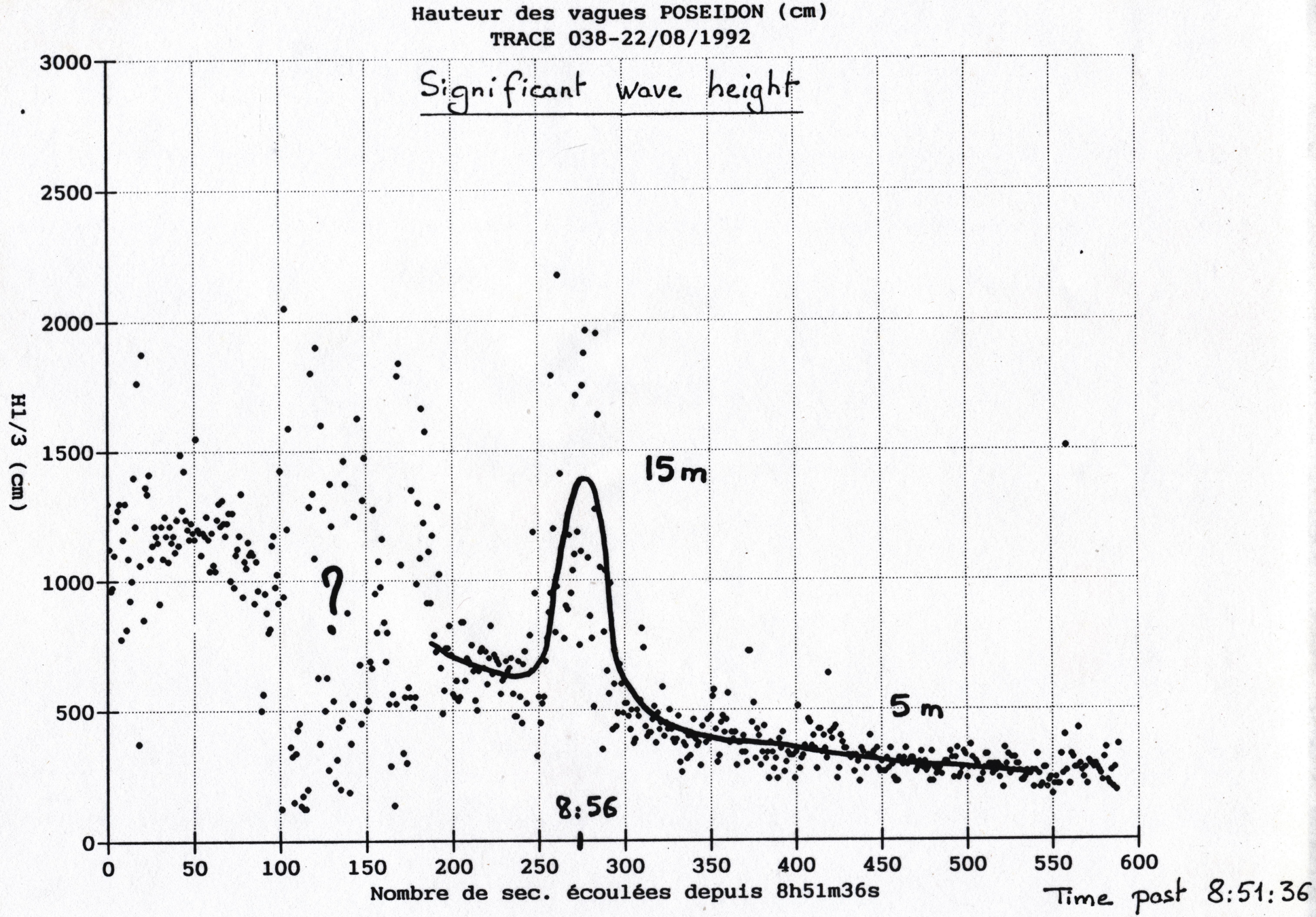
Hurricane Andrew

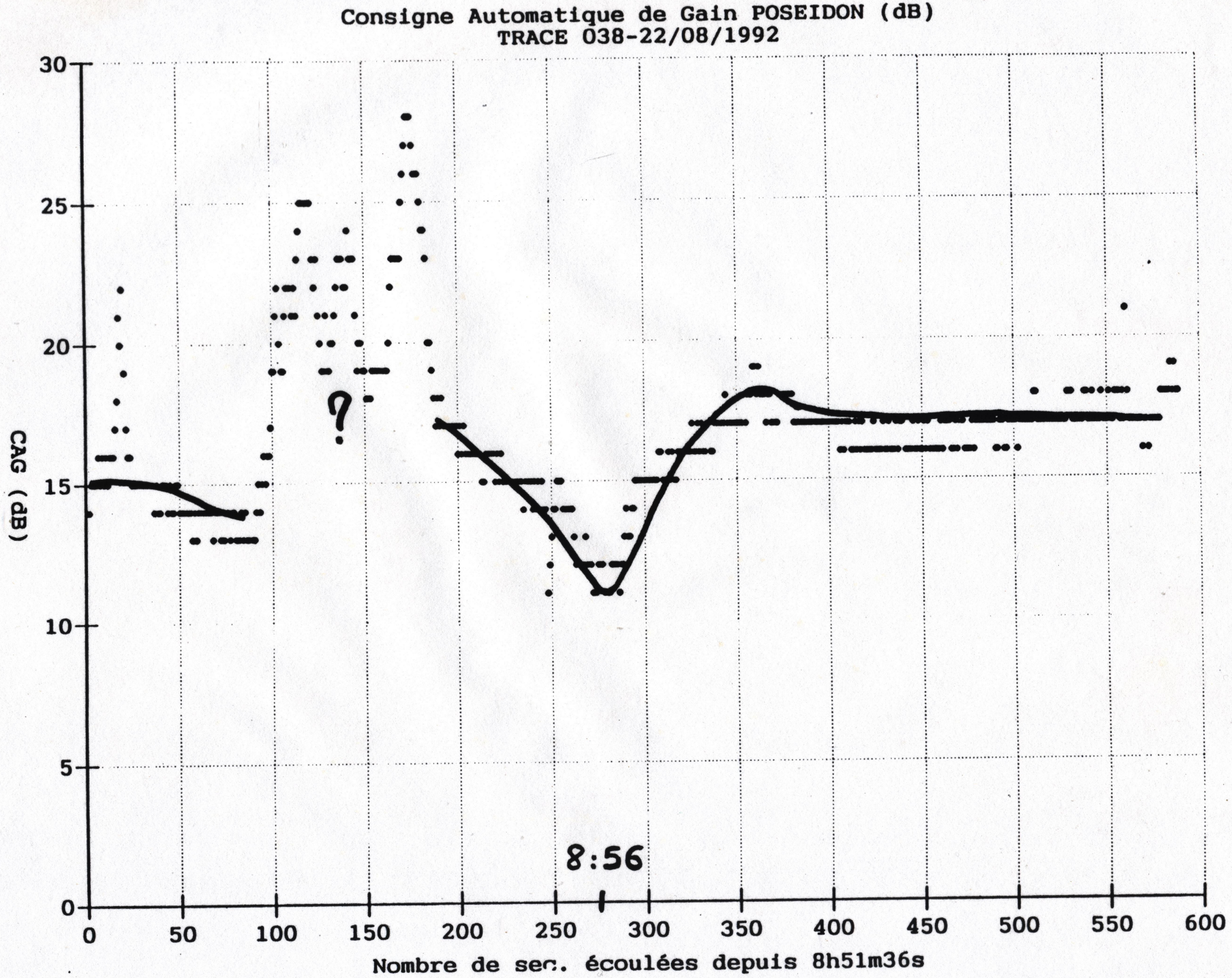
Hurricane overflight : August 22 at 8:56 am (UTC)

Effects detected by the altimeter :

- **Significant wave height large increase**
- **Decrease of received power (AGC increase) due to wind speed**


TRACE 038-22/08/1992
8h51m36s
08/22 0h
08/23
ANDREW
Trace TOPEX
9h01m24s
LATITUDE (deg.)
LONGITUDE (deg.)
40
35
30
25
20
15
10
5
0
-90
-85
-80
-75
-70
-65
-60
-55
-50


Hauteur des vagues POSEIDON (cm)
TRACE 038-22/08/1992
Significant wave height
H1/3 (cm)
3000
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
450
500
550
600
15m
5 m
?
8:56
Nombre de sec. écoulées depuis 8h51m36s
Time past 8:51:36


Consigne Automatique de Gain POSEIDON (dB)
TRACE 038-22/08/1992
CAG (dB)
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
450
500
550
600
?
8:56
Nombre de sec. écoulées depuis 8h51m36s